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BIOCYBERNETIC CONTROL IN MAN-MACHINE INTERACTION:
FINAL TECHNICAL REPORT 1973 - 74

Jacques J. Vidal, et al

California University

Prepared for:

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December 1974

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BIOCYBERNETIC CONTROL IN MAN-MACHINE INTERACTION: FINAL TECHNICAL REPORT 1973-74

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COMPUTER SCIENCE DEPARTMENT

School of Engineering and Applied Science
University of California
Los Angeles

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This research program aims at incorporating EEG "evoked responses" in man-machine communication. Present work is toward developing a methodology for the real-time computer discrimination of evoked responses in the EEG.

Current experiments use visual evoked responses using colored and patterned visual stimuli. From the ensemble of these experiments, tentative candidate EEG codes have emerged that appear to reflect three retinal processes (red-

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green-blue). These are remarkable results since, while there is good evidence for a trichromatic absorbing structure in the fovea, there was no indication that these processes would be reflected into scalp potentials.

Topological Dimensionality studies showed that red and green components, although close in timing, did behave in a clearly distinct manner. The response of the dark adapted eye, a limit case in background levels, was found clearly detached from the cluster in all cases.

Multi-channel single epochs from the same experiments, have been analyzed off-line using stepwise discriminant analysis. The stimulus sets have proven extremely effective in providing on-line discrimination. From the resulting discriminant functions, time windows for the component codes have been established.

In a separate study, data compression has been successfully achieved with the replacement of the single evoked response by the point processes formed by the peak instants in the positive or negative directions. It is expected now that a combination of short event detection with amplitudes at selected times will provide encoding of the evoked response in a particularly economical manner in man-machine communication.

The experiments have raised continuous challenges to the computer system and required some additional developments. A special "code cracking" software package has been implemented on the IBM 360/91 at UCLA and is now accessible through the ARPANET.

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CONTENTS

The following documents have not been included in the present report to reduce bulk:

The BCI EEG Data Format	(BCI 120173) 9 pages
The Monitor User's Guide	(BCI 020574) 48 pages

Both are computer-based documentation maintained on-line as part of the laboratory system. They are available on request.

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

SUMMARY

This is a research program that seeks to incorporate EEG "evoked responses" to complement overt behavior in specific man-machine communication schemes involving various aspects of decision making. Behind the experimental strategy is the view that the EEG in evoked responses is made up of a complex of wavelets that reflect individual and sequential events in the brain and in particular the cerebral cortex. The rules for appearance of these elementary wavelets would be the "syntactic" constraints upon a neuroelectric language with the wavelets acting as individual signatures for various aspects of the neural transactions that follow presentation of a stimulus. Once identified, the reliability and stability of those signatures can be reinforced naturally in the man-machine communication scheme, in a way amounting to operant conditioning. Thus the approach is centered on sequential events of short duration in bio-electric potentials and the relation between these sequences, behaviors and brain states. Those could in fact lead to a new model for the phenomena of evoked responses in the EEG.

Current experiments are aimed at visual evoked responses using colored and patterned visual stimuli, void at first of any cognitive or emotional content. Color flashes and patterns are choice stimuli that would provide potential support for non-verbal symbols in a man-machine communication language. In the color experiments, both target and intensities in each color are varied separately. From the ensemble of these experiments, tentative candidate EEG codes emerged that appear to reflect three retinal processes (red-green-blue). Best results have been obtained with a yellow background apparently because of the red-green depression caused by retinal adaption to yellow light. This allows the blue component, which had been elusive before, to appear much more clearly. These are remarkable results since, while there is good evidence for a trichromatic absorbing structure in the fovea, there was no indication that these processes would be reflected into scalp potentials.

Topological Dimensionality studies of the same data showed that red and green components, although close in timing, did behave in a clearly distinct manner. In addition the response of the dark adapted eye, a limit case in background levels, was found clearly detached from the cluster in all cases. Simultaneously multichannel single epochs from the same experiments, have been analyzed off-line using stepwise discriminant analysis with and without the detour of an orthogonal transformation. The results have been startling; the stimulus sets have proven extremely effective in providing a quality of discrimination that was unheard of with single EEG epochs, using only ten amplitude samples. Various representations were attempted, among which the replacement of the single evoked response by the point processes formed by the instants at which a single epoch was displaying a peak in the positive or negative direction. Cumulative histograms of those micro-events were found to be as stimulus-specific as are the averages, and it appears that some of the observed peaks correspond to the firing of specific nuclei. This raises great hope that a combination of short event detection with amplitudes at selected times will provide encoding of the evoked response in a particularly economical manner in man-machine communication. Already at this time, even without the benefit of amplitude information the peak "message" has equivalent clarity or discriminability, when compared to the peak histogram, than the single epoch with respect to the average.

The experiments have raised continuous challenges to the computer system and require additional developments. The central software package has been successfully implemented on the IBM 360/91 at UCLA and will be accessible through the ARPANET. It consists of a sequence of "code cracking" programs operating on epoch oriented data that will be ultimately used interactively. Several hardware improvements were made on the indigenous laboratory computers and the high-speed link that connects the laboratory to the 360/91. A tape drive and line printer controller were added to the SDS 920. Long vector hardware was successfully retrofitted on the IMLAC PDS-1 to allow the creation of pattern stimuli under computer control.

Following recent directives, the whole system has been re-evaluated in view of its potential role in the program of data sharing and interconnection between Biocybernetic Laboratories. Special attention has been given to the articulation of the BCI software package with software resources at MIT-MULTICS. Finally a remote hardwired terminal connection between CCBS and BCI has been implemented and is now in operation.

HUMAN EVOKED RESPONSE EXPERIMENTS

In 1929 Berger demonstrated the possibility of recording brain waves from the intact skull. Since then, an enormous amount of brain wave data covering a variety of conditions has been accumulated by neurophysiologists, and in recent years, computers have been used extensively for analysis.

Overall characteristics of these fluctuations of electrical potential can be somewhat predicted in relation to the electrode site, the mental state of the subject, and the presence and type of sensory stimulation. Some of those characteristics are readily identified by eye. Well-known examples are recognition of alpha activity and the phenomenon of alpha blocking, sleep and barbituate spindles, and the 3-per-second spike and wave complex of petit mal epilepsy. More subtle information in the EEG signals, however, requires computer analysis.

This "spontaneous" or "on-going" electrical activity is somewhat rhythmic in nature. The analysis of these rhythms has retained much of the early attention paid to brain waves in general. Yet it is increasingly evident that rhythmic activities contain little information in themselves and that their function is probably similar to that of a carrier. The general picture is that idle nervous tissue will exhibit spontaneous oscillation or rhythm while activity or commitment of the same tissue to an active function will be denoted by desynchronized random-like oscillations.

Beyond gross differentiation of brain states, it seems that information coding in the EEG wave should be sought in the specific waveforms generated in time. By contrast with the wide spread character of oscillations, the wave shapes obtained with "evoked potential" are localized and correspond well with underlying post-synaptic potentials. Evoked potentials (evoked responses) are generally obtained with a light flash, brief sound, or touch of the skin which generates in the corresponding sensory cortex (visual, auditory or somesthetic), a localized electrical response in the form of an aperiodic waveform lasting up to half a second and superimposed on the ongoing background activity. In general, repeated stimuli and averaging of the waveforms have been used to reveal the "evoked" response by cancelling the background "noise".

Indeed early investigations in 1965 by Fox and O'Brien resulted in the demonstration that stimulus-evoked potentials were directly related to the probability of firing of any particular cell in the area of population included in the brain wave recording. Specifically, the studies showed that in these cortical cells, the probability of firing could be described almost precisely by the shape of the slow wave associated with that same electrode. Thus, the relationship between single-cell spikes and evoked potential was dramatically clarified.

Fox and Norman demonstrated that the spike-wave relationship would also hold for spontaneous activity of the cortex. The next step then was to determine if these potentials might represent behavior, based on these earlier studies which showed that the moment-to-moment changes in amplitude and polarity of the slow activity of the brain represented moment-to-moment changes in probability of firing of single cells.

To achieve this took a novel approach. Fox and Rudell for the first time used operant reinforcement techniques to increase or decrease the probability of occurrence of some component of the visual evoked potential. This they claimed was tantamount to asking the animal whether, under reinforcement control, it could increase or decrease the probability of some aspect of his brain wave. In turn this was equivalent to asking whether or not the animal had any behavior available for reinforcement, which utilizes, encodes or is represented by the particular aspect of brain activity chosen.

To pursue the study of this brain-behavior relationship to time-dependent behaviors, Rosenfeld and Fox trained unrestrained cats with implanted electrodes to make discrete paw movements. At the same time the mixed sensory-motor potential was recorded in the cortex. These data, treated correlatively, showed a relationship of early waves and early portions of each movement and of later waves and later portions of each movement, but relative independence of early and late measurements.

In the second part of these experiments a particular aspect of the movement-evoked potential in the cortex was chosen and by reinforcement control, the animals were trained to increase the probability or amplitude of this particular component of the brain wave. Exactly in accordance with prediction, the animals, when this training was accomplished, altered some aspect of their limb movements. To the discrete changes of the cortical evoked potential associated with movement, corresponded some discrete and finely detailed changes in some aspects of the movement of the limb, showing that spontaneous activity of the brain from moment-to-moment encodes function and the sequential probabilities of single-cell firing were functionally represented by the sequential and momentary changes in brain waves. More important, moment-to-moment changes in behavior were discretely reflected in moment-to-moment changes in sequential brain waves.

These findings in animal studies are very significant insofar as they point out the functional meaning of the "gross" EEG potentials generated by populations rather than single neurons. In other words, at least in some conditions, the neural "roar" does not cancel out into hopeless noise. With humans and without implanted electrodes, the difficulties are certainly compounded. But in compensation more avenues are open for operant conditioning, a technique that may well be the key to success in identifying the EEG "codes".

A starting point in this study was the recognition that different stimuli with specific set of features evoke distinguishable electrical "signatures" on the scalp. For instance, the response to the brief flashing of a figure made of vertical lines will yield a waveform markedly different from that obtained from a set of circles. In fact, the presence in the evoked waveforms of clear correlates of the modalities of sensory stimulation has been abundantly demonstrated.

Of particular interest are studies dealing with visual stimuli (White and Eason, 1966; Harter and White, 1968, 1969; Clynes and Kohn, 1967; Rietveld, et al, 1967; Spehlmann, 1965; Spekreise, 1966). The evoked electrical signature on the cortex does however include more than a mirror conversion of the stimulus content. In fact only the early part of the response appears to be directly stimulus bound, while the "late" components appear to relate to more complex brain functions related to the stimulus such as its perception and meaning.

The general approach was defined as follows in the original proposal: First, stimulus sets are selected that span some "dimensions" expected to elicit neural correlates, that is, changes in evoked response. Next, wave components in the neural response are identified that appear to correlate with each stimulus dimension, thus providing a first identification of the "candidate" code, along with its sensitivity and stability. In this phase the model-free topological dimensionality analysis is applied to the data to reveal its parametric dimensionality in relation to each stimulus dimension. Outcome "candidate" waveforms or parameters are then isolated and compared from subject to subject. For each subject the reliability and stability of the emerging dimensions must be evaluated in repeated experiments. As the initial bioelectric configuration emerges from dimensionality analysis, an interactive closed loop mode is entered. Operant conditioning techniques are applied to individualize and sharpen these waveforms.

Current experiments are aimed at the conditioning of selected attributes of visual evoked responses and are using colored and patterned visual stimuli (void at first of any cognitive or emotional content). Color flashes and patterns are choice stimuli that would provide potential support for non-verbal symbols in a man-machine communication language. Eventually the cognitive or emotional content of the stimulus was to be considered (e.g. whether the subject has directed his attention towards a specific feature in the complex stimulus, or whether the occurrence of the stimulus represents a gain or a loss in a game playing situation-- or whether the stimulus is varied in a dimension varying from pleasant to aversive). These extensions are to be attempted during the second and third year.

A brief review of the basic laws of color vision will be given next as an introduction to the experiments on evoked response to color.

TRICHROMATICITY

The essential trichromaticity of color vision has been demonstrated by the results of color mixing experiments using psychophysical technique for making color judgment, i.e. using the eye as a null instrument. Any spectral color can be matched by the proper mixture of any three colors, as long as none of those is a combination of the other two.

A color stimulus can be characterized by its C.I.E. (Commission International de l'Eclairage) tristimulus values (X, Y, Z) i.e. by the relative amount of three standard C.I.E. priorities that have been required by the "standard observer" to match the stimulus. Tristimulus values and luminosity functions (visual efficiency) in function of wavelength (i.e. for pure colors) are given in standard tables together with the spectral irradiance of the three C.I.E. standard sources (A, B, C).

The standard chromaticity diagram (Fig. 1) provides a two-dimensional characterization of a color stimulus. The "chromaticity" coordinates are given by:

$$x = \frac{X}{X\ \ Y\ \ Z} \ ; \qquad y = \frac{Y}{X\ \ Y\ \ Z}$$

On the diagram the colors obtained by mixing two others will lie on a straight line connecting the two points. The curved boundary line is the locus of the pure spectral colors, and the area within this boundary contains all the colors that can be made with lights, with white at the center.

The simplest theory of the mechanism of color vision, proposed by Young and Helmholtz, postulates that there are exactly three different receptor pigments in the eye, which respond maximally to, say, red green, and blue wavelengths. These three channels of information are then processed somehow by the visual system so that colors can be perceived.

The laws of color mixing can be demonstrated to be a consequence of this proposition, but since we can make any kind of linear transformation of the color coordinates that we want, we cannot determine uniquely what the three receptor absorption curves are simply on the basis of color mixing experiments.

COLOR RECEPTORS

For several decades a number of workers have focused their attention on the problem of determining the nature of the visual photopigments. The most definitive data has come from the microspectrophotometry of Marks, Dobelle, and MacNichol, in 1964, and similar work by Brown and Wald, 1964. Marks et. al. (1964) present data from measurements taken on ten primate cones and two human cones from the parafoveal region. Their procedure included the use of an "end-on" preparation of retinal receptors, so that the measuring light beam passed through the receptor in the normal direction. They simultaneously passed a reference beam through a "blank" spot in the preparation, and the ratio of the intensity of the two beams was measured automatically over the range of 390 nm to 670 nm.

An overview of the results, including primate cones, reveals three major classes of receptors with maximum absorption at about 445, 535, and 570 nm. One of the human cones showed maximum absorption at 457 nm, indicating that it was a mediator for blue sensation. The other human cone tested by Marks, et. al. (1964) was probably a red receptor, with its peak absorption at 575 nm.

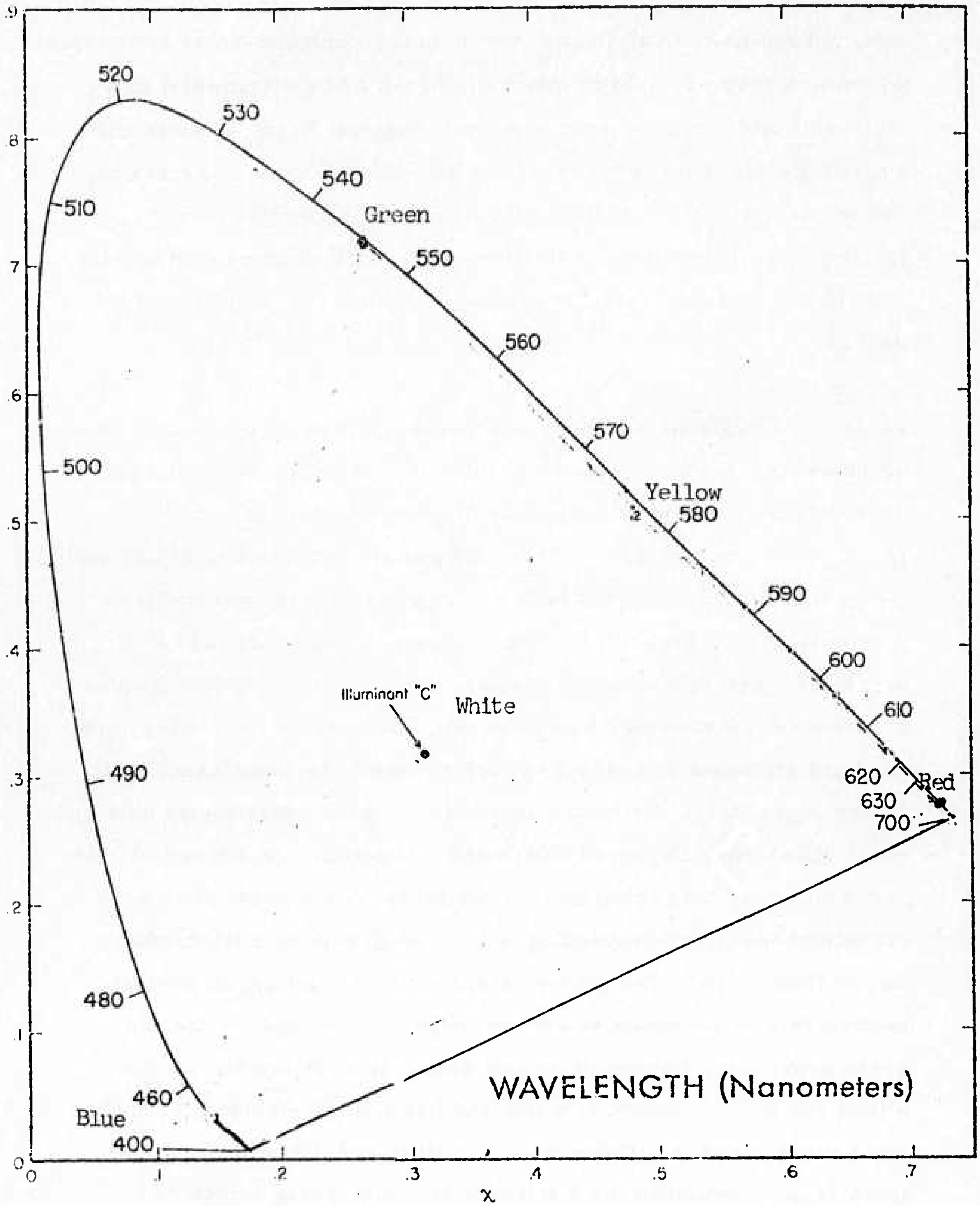
The absorption difference spectra from the majority of the "red" cones showed a secondary hump or peak near 555 nm suggesting the possibility that single "red" receptors may contain red and green pigments, coexisting in a single cone.

Brown and Wald (1964) measured the difference spectra of 4 human cones using a similar "end-on" preparation from the parafoveal region of the retina. Their technique differed from Marks, et.al. (1964) in that they took a difference spectrum, i.e., they obtained the absorption spectrum, then bleached the receptors with a bright flash of light and obtained a bleached absorption spectrum. The difference between the unbleached and bleached absorption spectra is the difference spectra. Brown and Wald's data represent one blue receptor, two green-receptors, and one red receptor. The peaks in these curves fell at about 450, 525, and 555 nm. The blue-receptor peak of 450 nm agrees well with Marks et.al. blue receptor which peaked at 457 nm, but the gree and red-receptor peaks seem to occur at somewhat shorter wavelenghts than was found earlier by Brown and Wald when relatively large patches of human fovea were measured.

TETRACHROMATICITY

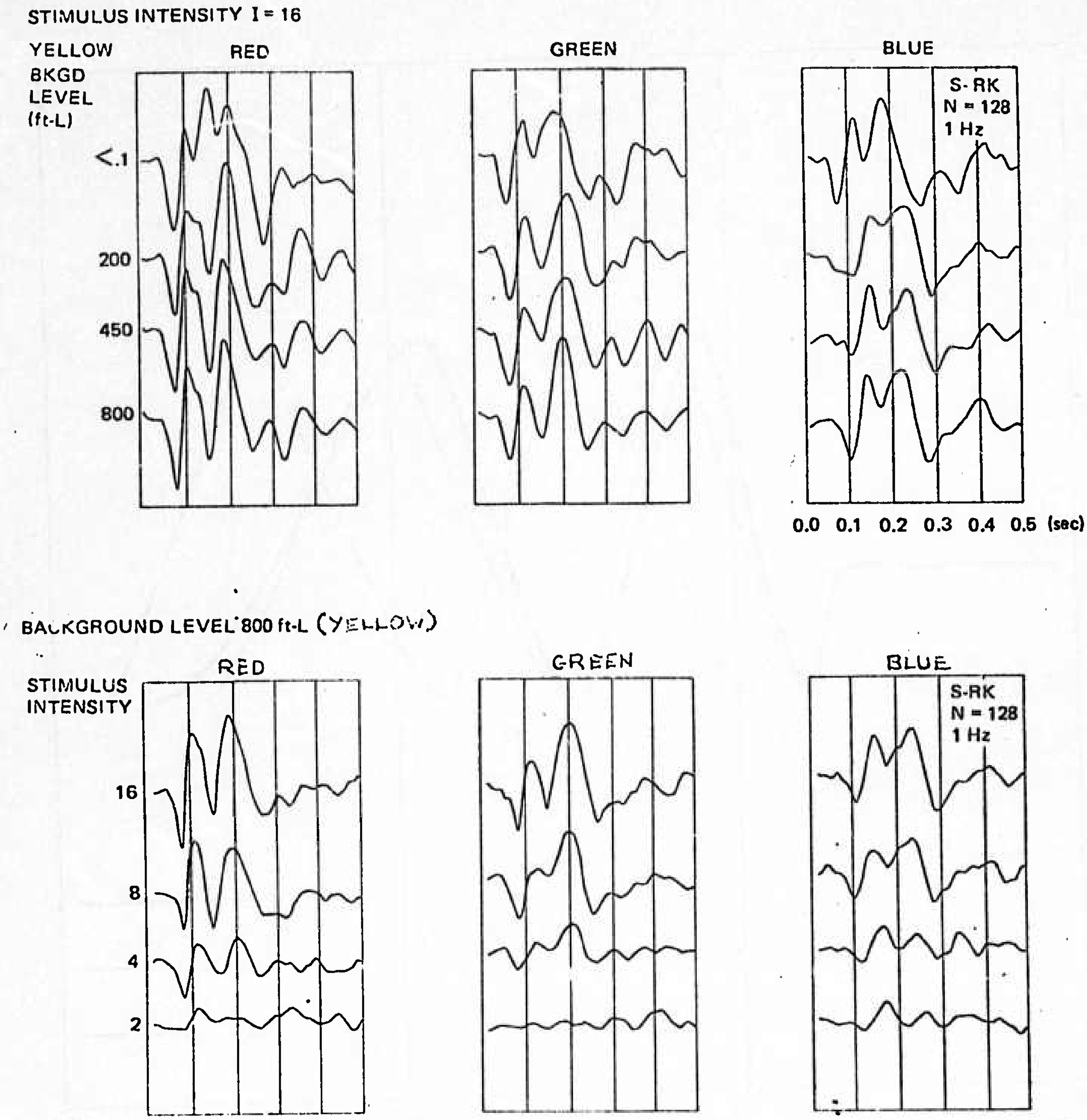
It is often stated that there are four "psychologically unique" colors; red, yellow, green and blue. These lead to the so-called opponent-color theories, such as those proposed by Hurvich and Jameson (1955). The blue, green and yellow primaries are also special in that they do not undergo a Bezold-Brucke shift; that is, their hue is invariant with changes in luminance. Psychometric experiments show red and green as antagonistic colors; their mixture, yellow, is not perceived by subjects as either red nor green. Conversely, blue and yellow lights mix to form white. Hurvich and Jameson (1955) have worked out a formal mathematical theory, based on the opponent-color hypothesis, with which they are able to match predicted and experimental data quite well for various phenomena, including the Bezold-Brucke shift, wavelength discrimination, spectral saturation, and color mixture. These results are not surprising since their chromatic response functions are linear transformations of the CIE mixture curves with the addition of four "variable constants" which are manipulated for best fit.

Color theory is still evolving, and it was felt that this was an area in which evoked response studies could make an important contribution. This choice provided an extremely fortunate collaboration with Dr. C.T. White at NEL. Indeed, his preliminary data indicated that a paradigm of this type would be a very rich vein for our purpose. A sample of that preliminary data is shown in Fig. 2. There, average evoked responses are shown to red, green and blue flashes presented against yellow backgrounds. Background level on the one hand and stimulus intensities in each color on the other hand, were varied separately. From the ensemble of these experiments obtained under different background colors and intensities, tentative candidate codes emerged that accounted for the three hypothetical processes (at retinal level) corresponding to the red-green-blue trichromatic theory (Fig. 3). The yellow background was thought to produce particularly representative evoked responses because of the red-green depression caused by retinal adaption to yellow light. This allows the blue component, which had been elusive before, to appear much more clearly. These were startling results since, while there is good evidence for a trichromatic absorbing structure in the fovea (Fig. 4) there was no indication that these processes would be reflected into scalp potentials (collected in the occipital area). This finding also brings as a next question, the potential role of the opponent color theory developed from psychophysical



Chromaticity diagram for Standard Source "C" (artificial daylight). This shows the colors of various Kodak filters when they are illuminated by the Standard Source "C" specified by the International Commission on Illumination (CIE). This Standard Source "C" is approximately equivalent to average daylight, having a color temperature of 6750 K.

FIGURE 1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YELLOW BKGD LEVEL (ft-L)
RED
GREEN
BLUE
S-RK
N = 128
1 Hz
<.1
200
450
800
0.0 0.1 0.2 0.3 0.4 0.5 (sec)
BACKGROUND LEVEL 800 ft-L (YELLOW)
STIMULUS INTENSITY
16
8
4
2

Figure 2

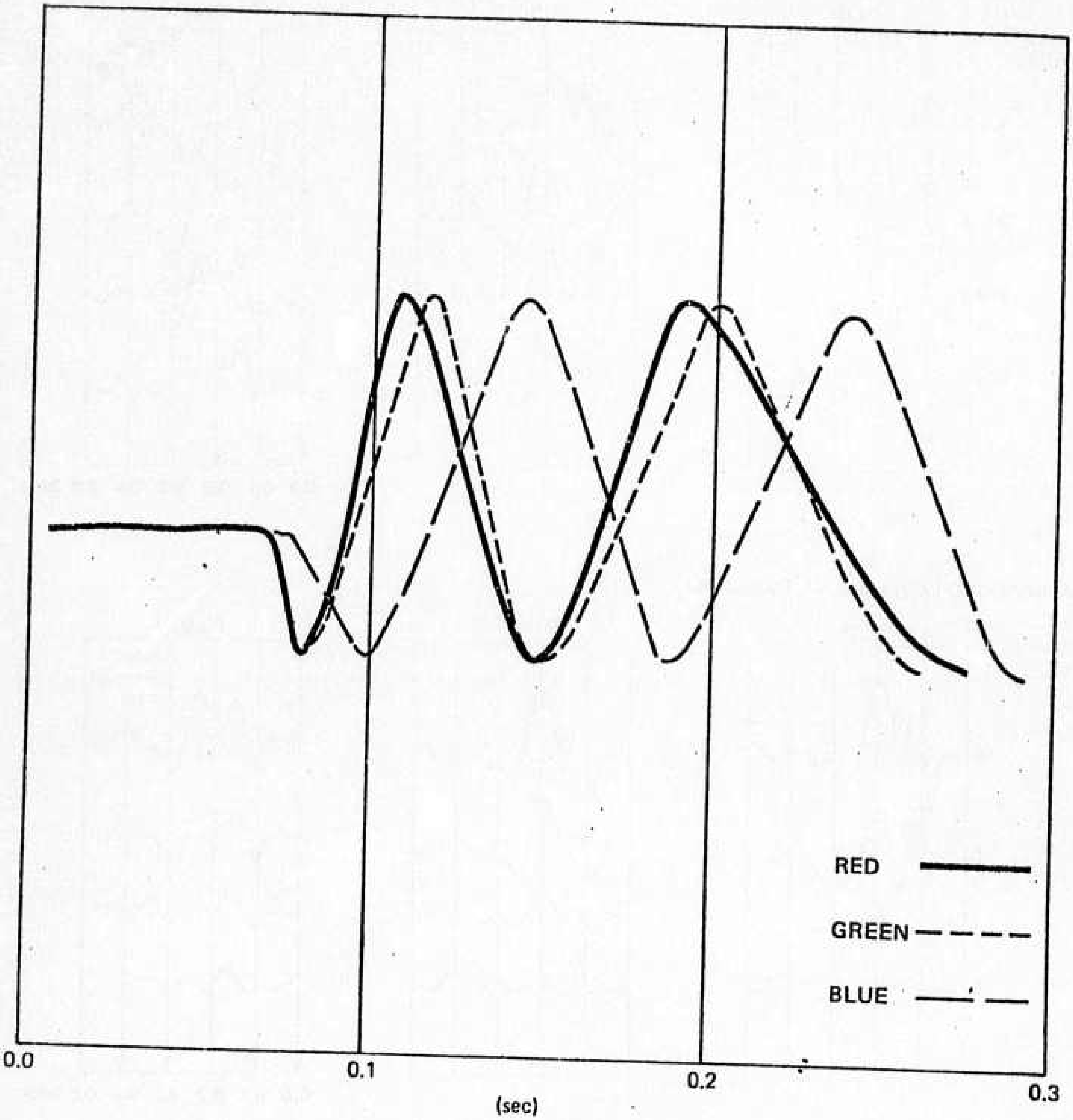
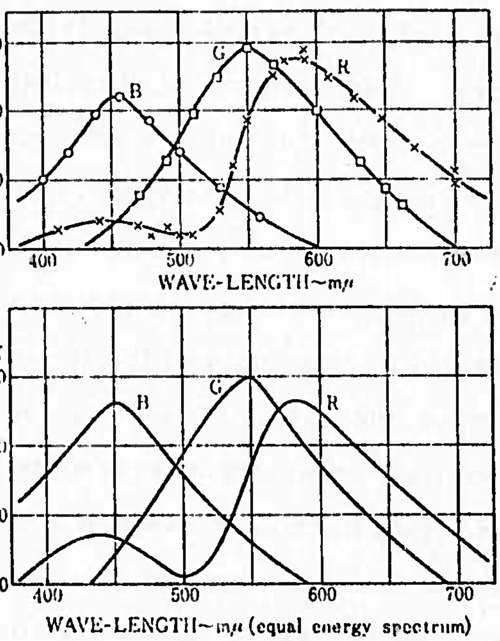


Figure 3



Curves showing dependence of magnitudes of the three basic retinal processes upon wavelengths of spectral lights, obtained from fovea of normal trichromat. (MOTOKAWA, 1949.)

Figure 4

experiments.

Topological Dimensionality studies of this early data showed that red and green components, although very close in timing, did behave in a clearly distinct and quasi-orthogonal manner with respect to each other when background or stimulus intensities were changed (Fig. 5). The response of the dark adapted eye, a limit case in the background level series, clearly detached itself from the cluster in all cases. A fraction of this preliminary data was obtained at NEL without the benefit of automatic data acquisition and digitizing systems. Thus, single epochs had been lost and only graphic averages were available. Further analysis of these averages has been pursued with a borrowed graph pen to digitize plotted data. Since then, the experiments have been conducted at the Brain Computer Interface Laboratory and have been or are being analyzed through the BCI software package without resorting to averaging (except for the final displays). Twelve subjects have been evaluated on the basis of evoked response quality and relative absence of muscle artifacts and five have been retained retained. The BCI experiments are focused on single epochs (averages are actually irrelevant to the Biocybernetic goals.)

Meanwhile, on-line experiments have been done to further probe the fine structure of the EEG epochs and search for better primitives than amplitude samples. Particularly intriguing was the possibility that by adequate representation of the data, these primitives could be made explicit. Various representations were attempted, among which the replacement of the single evoked response by the point processes formed by the instants at which a single epoch was displaying a peak in the positive or negative direction (Fig. 6). In other words, the series of zero crossing instants for the first derivative of the amplitude function together with the sign of the second derivative. Cumulative

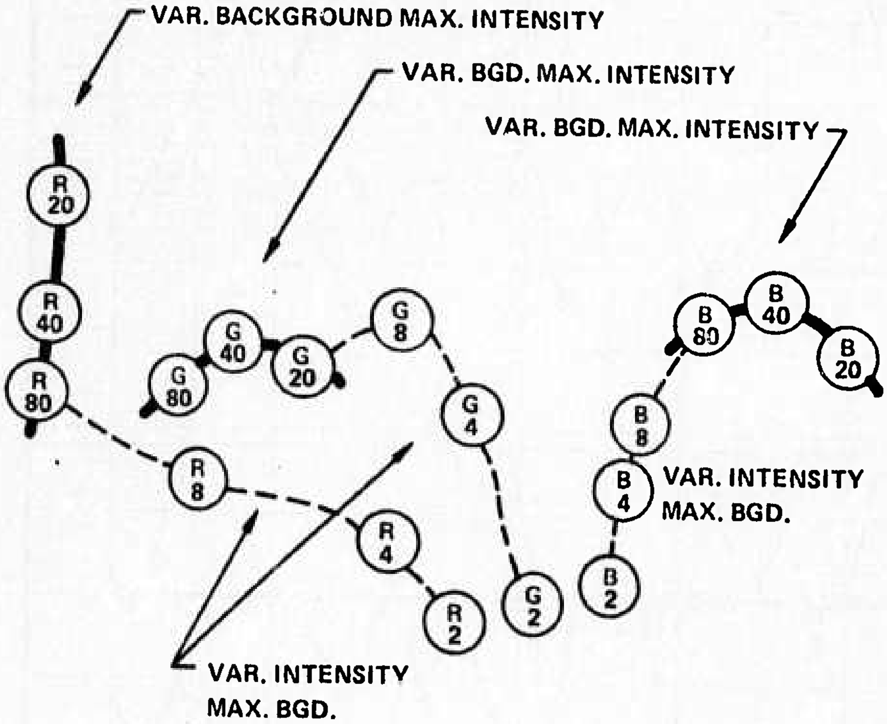
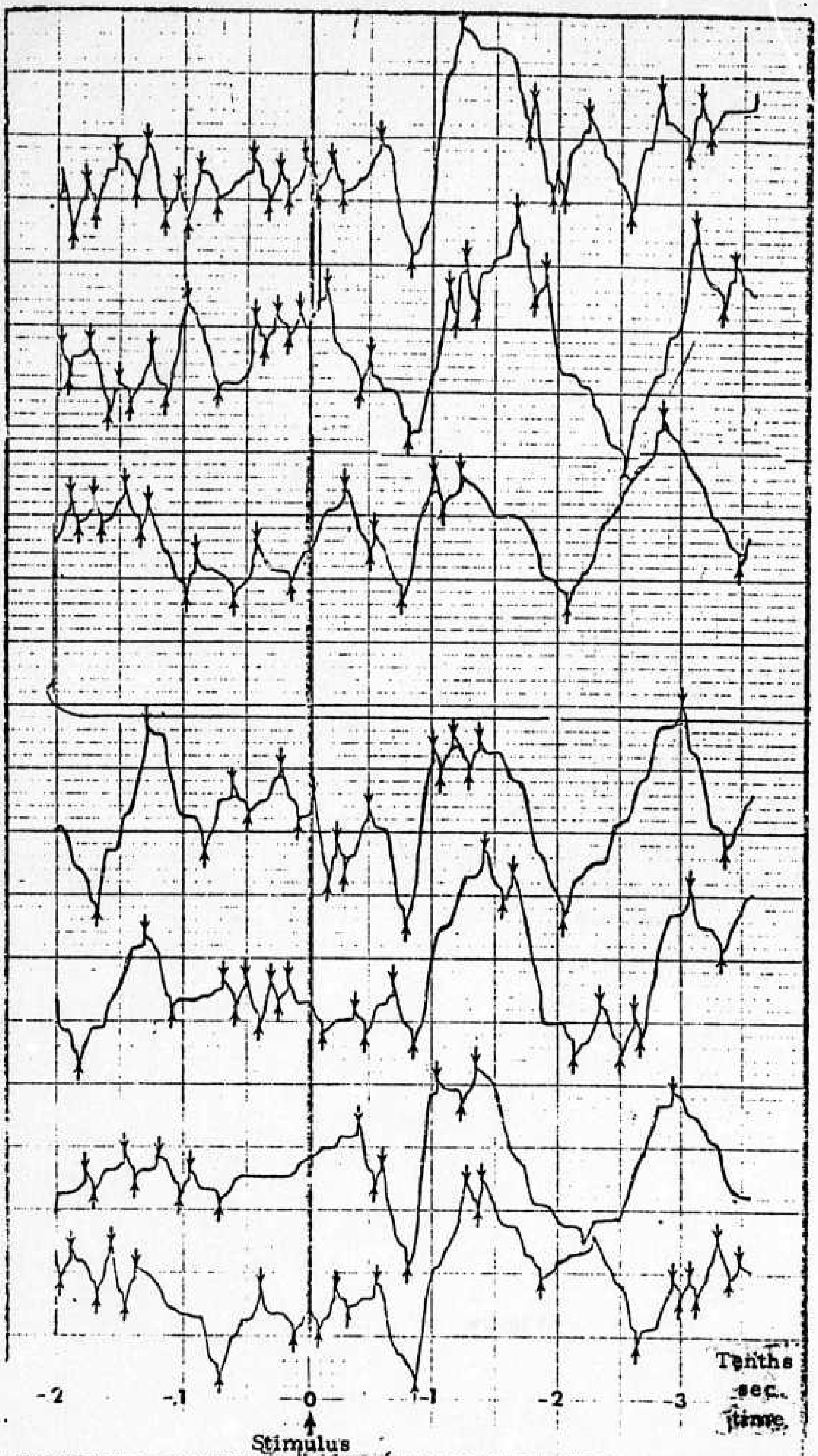

VAR. BACKGROUND MAX. INTENSITY
VAR. BGD. MAX. INTENSITY
VAR. BGD. MAX. INTENSITY
R 20
R 40
R 80
G 80
G 40
G 20
G 8
G 4
G 2
R 8
R 4
R 2
B 80
B 40
B 20
B 8
B 4
B 2
VAR. INTENSITY MAX. BGD.
VAR. INTENSITY MAX. BGD.

Figure 5



Single Epochs GP Red 3/Background Yellow 100

Figure 6

20

histograms of those micro-events were obtained and compared to the averages (Fig. 7). These histograms were found to be as stimulus-specific as are the averages. While the relationship between the histograms and the underlying slow wave, can be explained to some extent by the procedure itself (i.e. the "bunching" of the peaks by the slow wave), it has already been established that the stability and sharpness of some of the peaks could not be explained if the small peaks were just high frequency noise. Rather it appears that the slow wave conjugates with short events which may correspond to the firing of specific nuclei. This raises great hope that a combination of short event detection with amplitudes at selected times will provide encoding of the evoked response in a particularly economical manner in man-machine communication. Already at this time, even without the benefit of amplitude information the peak "message" has equivalent clarity or discriminability, when compared to the peak histogram, as the single epoch has with respect to the average.

A next move is underway to investigate the possibility that the peak set or some variation of it contains identifiable moment-to-moment information. Operant conditioning techniques are expected to provide some of the answers and various operant paradigms are being evaluated. Present results are still at a level of casual observations. Fig. 8.[illegible] for example, shows a run in which the reward (a conditioning) was attached to the presence of small positive peaks in the vicinity of 300 milliseconds. The growth of the amplitude of this component in the average is clearly seen in the graph.

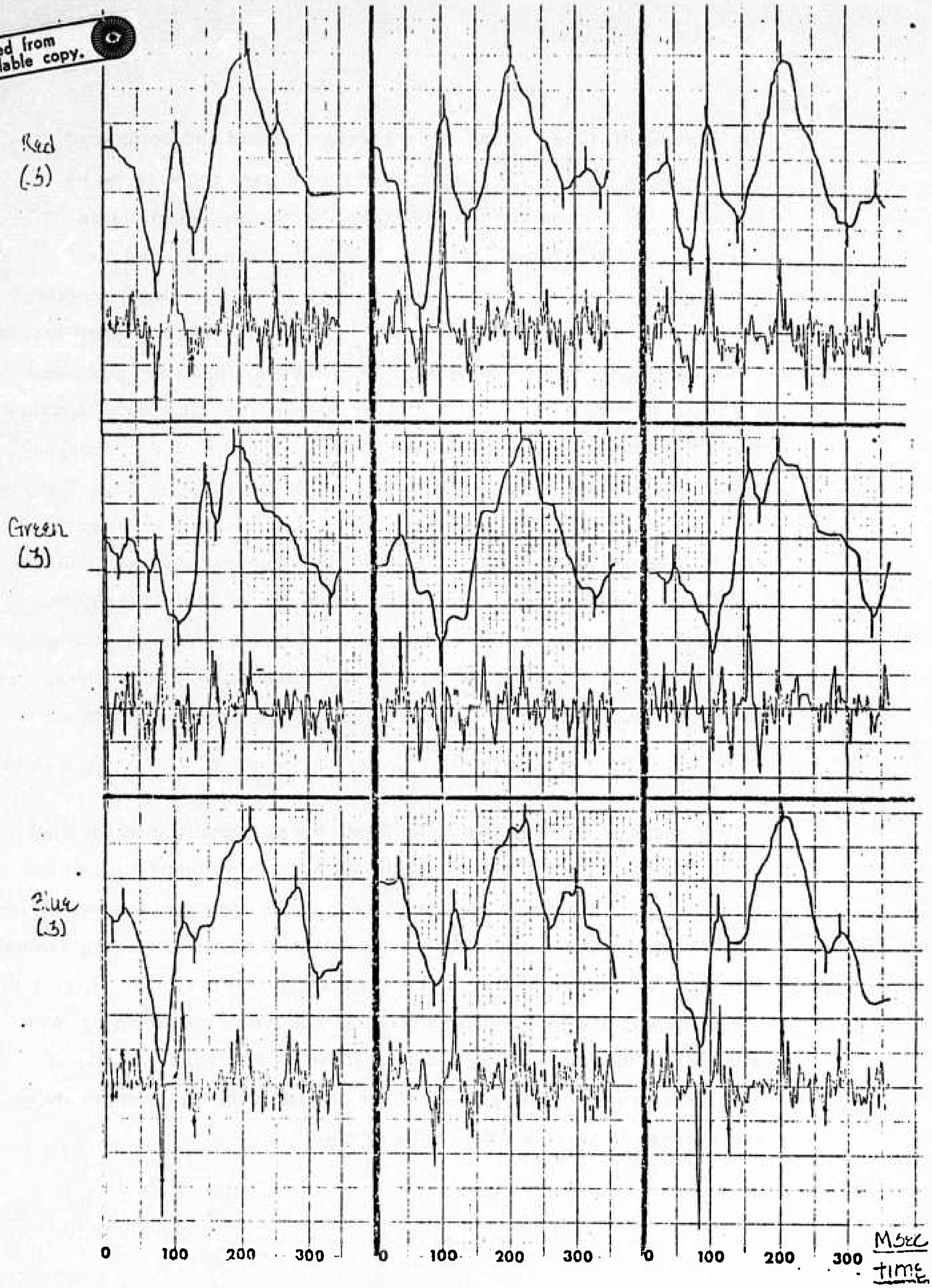


Figure 7

Amplitude Averages & Peak Histograms

(TB, N=30, BGD=Yellow 100)

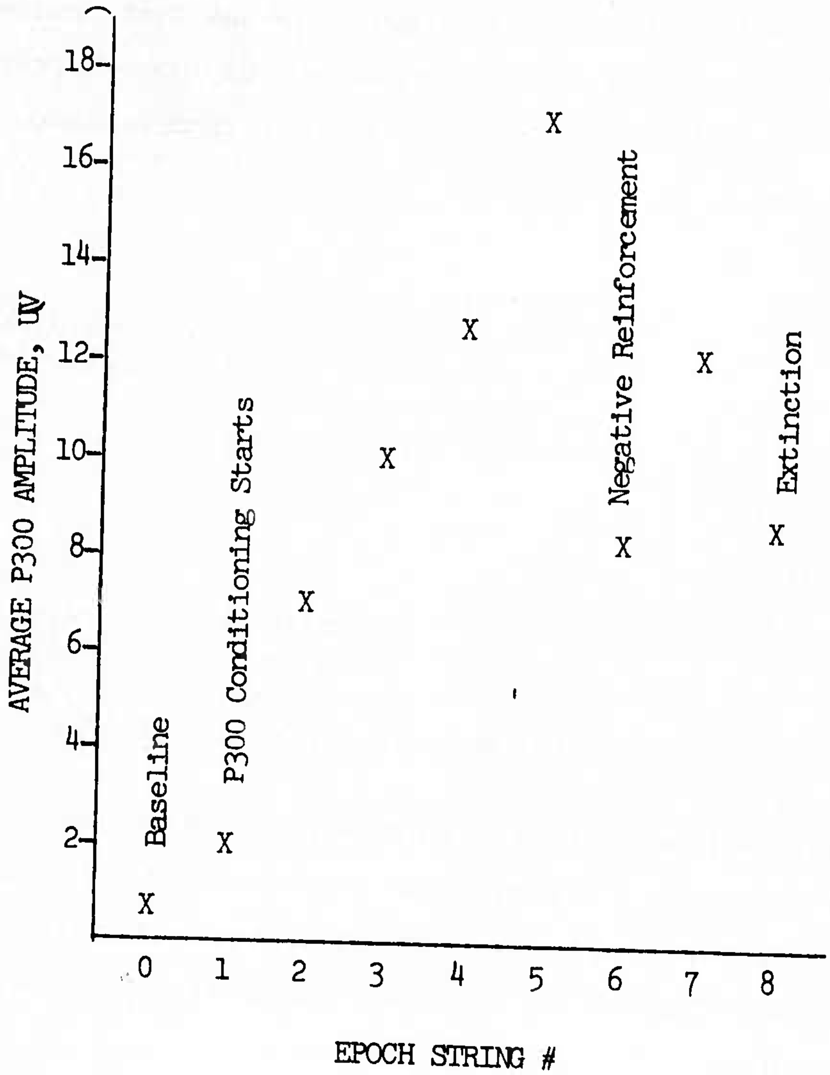

AVERAGE P300 AMPLITUDE, UV
18
16
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
EPOCH STRING #
Baseline
P300 Conditioning Starts
Negative Reinforcement
Extinction

FIGURE 8.

DATA ANALYSIS

Phase I

Data from one subject whose Evoked Potentials (EVPOTS) were extensively studied is presented next. This experiment consisted of 48 presentations of a flash of colored light of either red, green or blue hue, over a yellow background. The brain electrical activity was sampled for 5 seconds prior to and 320 milliseconds following each flash, from four electrode locations. A description of the experiment follows:

Exp ID:	Three Color Experiment		
Stimuli:	Flashes of red, green and blue. The flashes were non-random, i.e. three sequences of color flashes were used to record three batches of evoked responses		
No. of Epochs per group:	48		
Background:	Yellow		
Sampling Rate:	320 msec.		
Channels Recorded:	Channel 1	Frontal/Ears	F_{pz}/A_1+A_2
	Channel 2	Vertex/Ears	C_z/A_1+A_2
	Channel 3	Occipital/Ears	O_z/A_1+A_2
	Channel 4	(Eye) Inferior Orbital/Ears	

This experiment is not intended to represent the definitive color evoked response study; rather it is a vehicle for the evaluation of evoked response analysis techniques. The data have been analysed using stepwise discriminant analysis (SWDA) with and without pre-processing by the Orthogonal Transformation.

Some representative evoked response plots are shown in the following figures. Fig. 9 in the plot of Red, Green and Blue EVPOTS from Channel 1, Fig. 10 is from Channel 2, and Fig. 11 is from Channel 3. These plots are all averages obtained from 48 epochs of each of the three colors. The ordinate is in microvolts, positive up, the abscissa is time; there are 80 samples spaced 4 msec. apart. The flash occurred at time point 1.

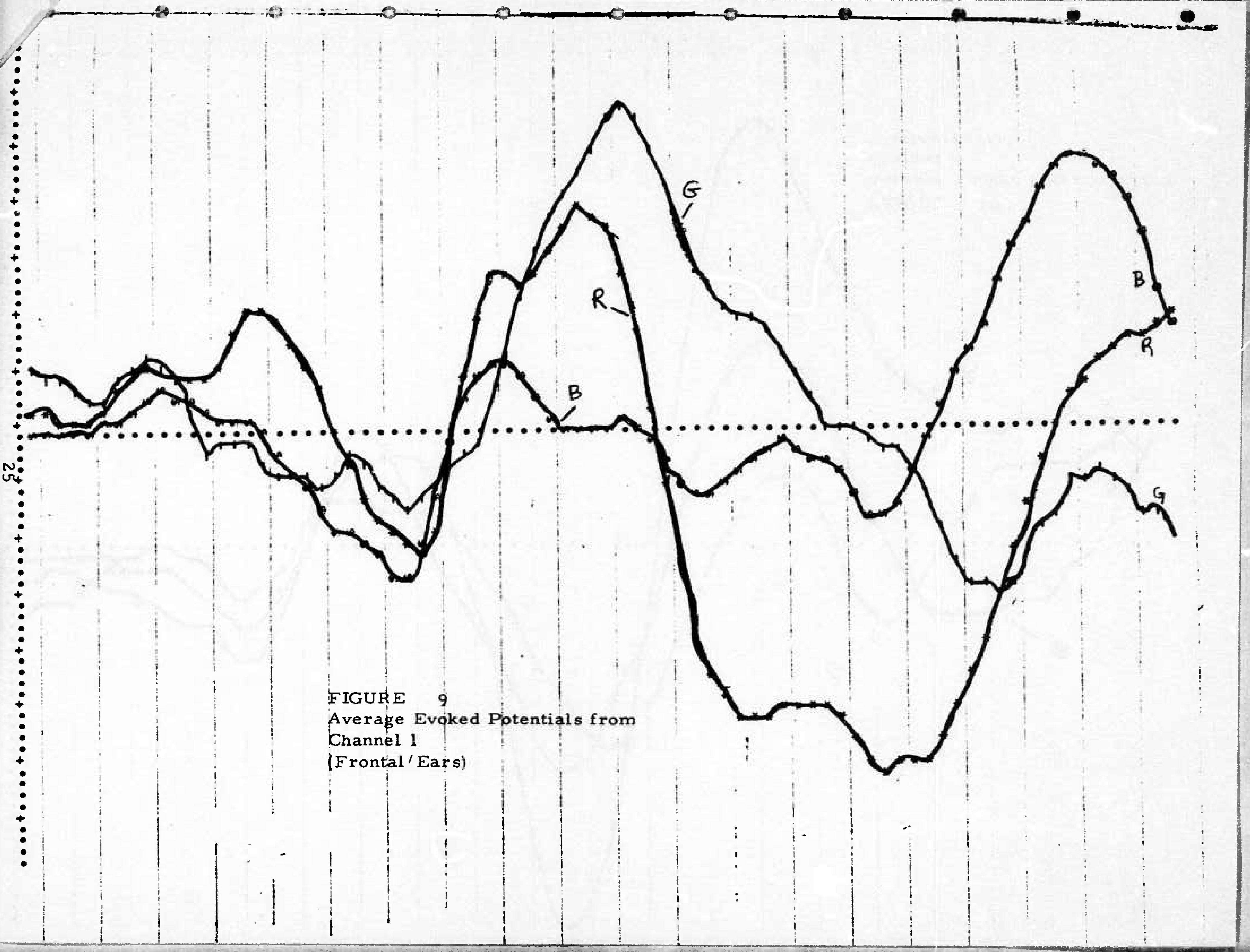


FIGURE 9
Average Evoked Potentials from
Channel 1
(Frontal/Ears)

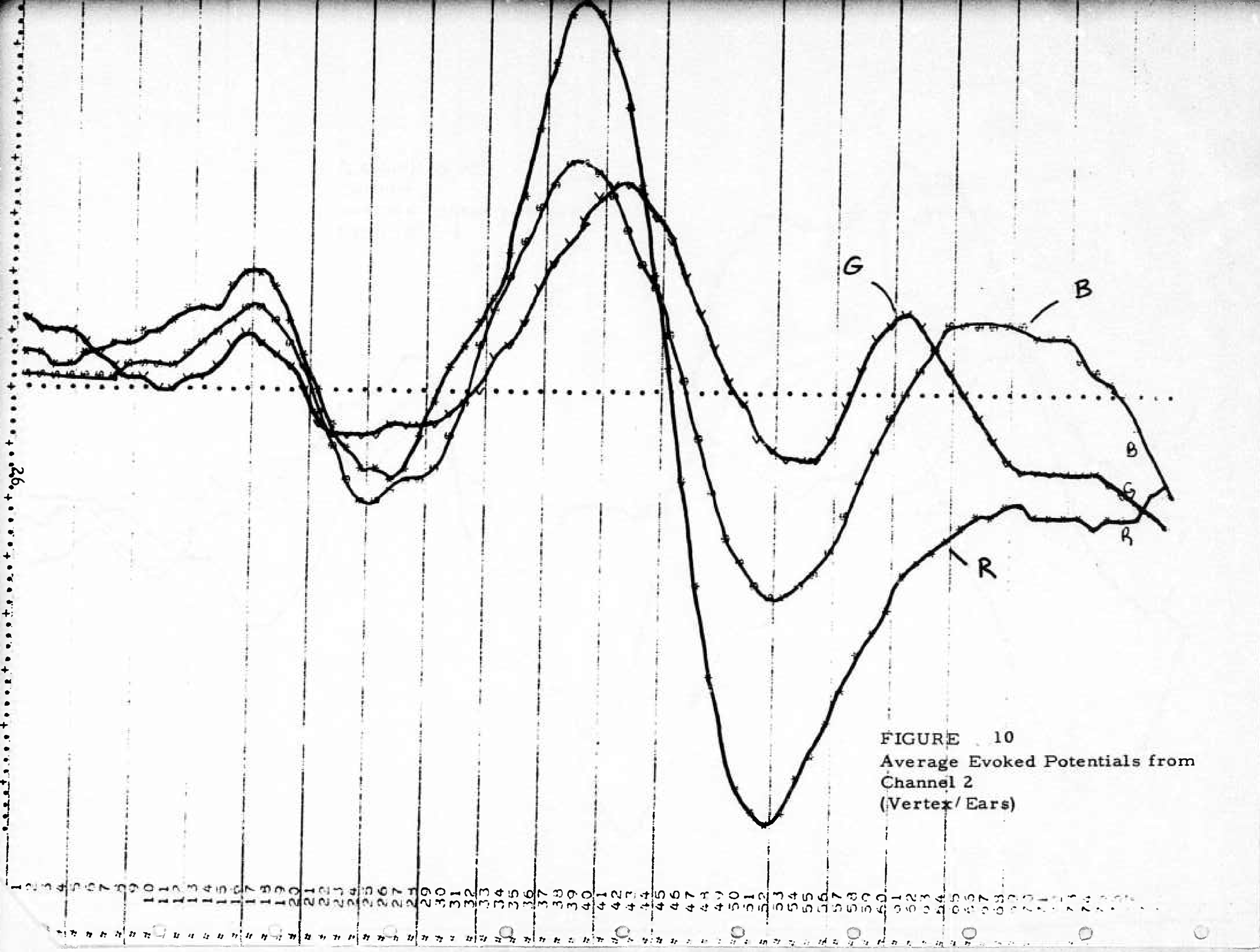


FIGURE 10
Average Evoked Potentials from Channel 2
(Vertex/Ears)

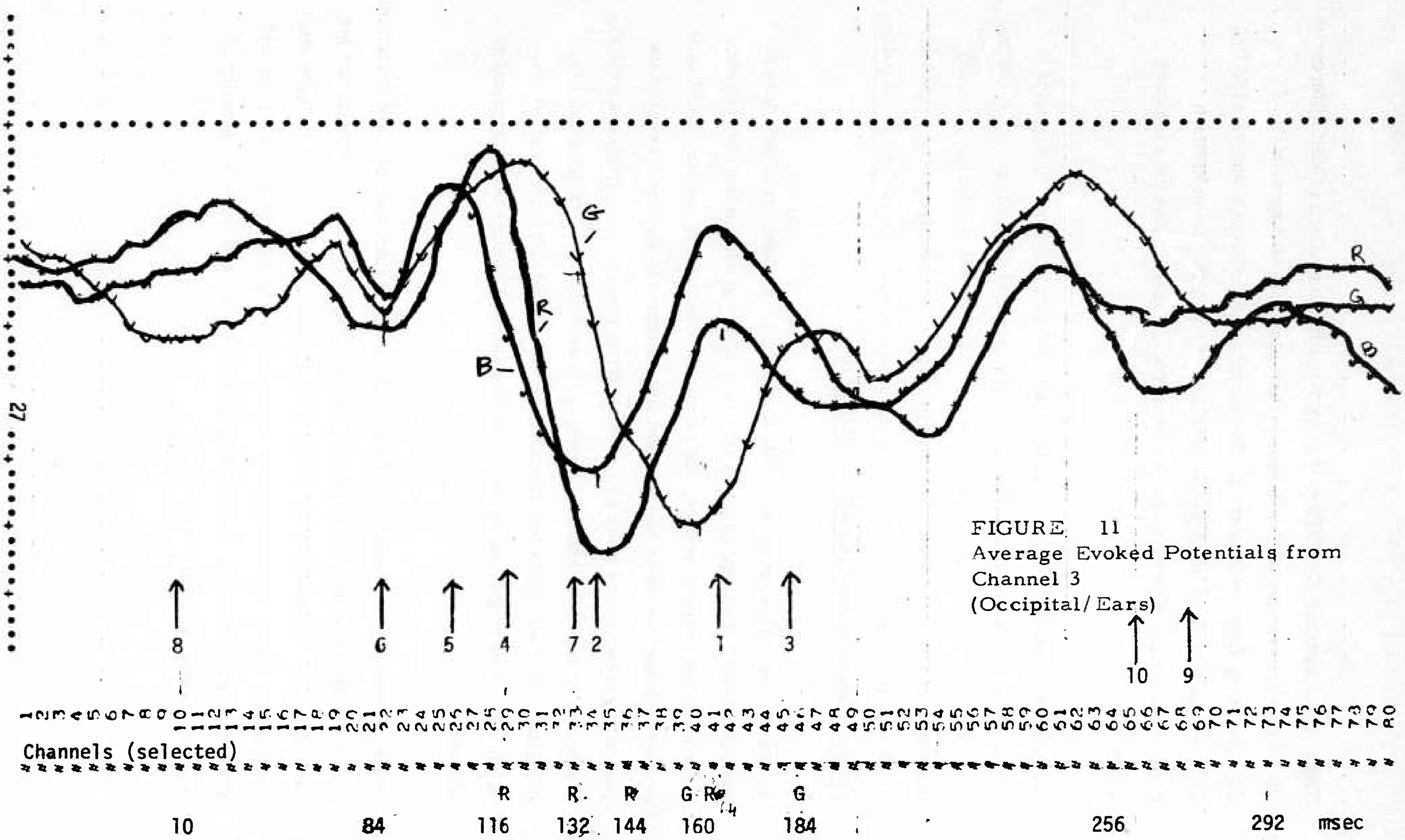


FIGURE 11
Average Evoked Potentials from
Channel 3
(Occipital/Ears)

Clearly, the average EVPOTS evoked by the different colors exhibit differences but we need a measure of how different they are, with an appreciation of the variability from trial to trial. The stepwise discriminant analysis (SWDA) program does provide an objective measure of the differences between these multivariate distributions, based on the variability and the regularity in the data.

The program computes a set of linear classification functions by choosing a subset of the original 80 variables in a stepwise manner. The variable entered at each step is selected according to one of four possible criteria; typically that variable will be chosen which has the largest F-to-enter. The F statistic which is computed at each step gives us an indication of the differences between groups relative to the differences within groups.

Typically, the SWDA program is told to select the 10 best variables, then it computes the coefficients of these variables which produces the best possible discrimination between groups, and prints a classification matrix. Each case (epoch) is evaluated using the discriminant function (D. F.) developed and its posterior probability of belonging to each group (color) is computed as well as the square of the Mahalanobis distance from each group. The program also computes the coefficients for canonical variables and plots the first two canonical variables to give an optimal two-dimensional picture of the separation of groups.

Other measures generated by SWDA include group means and standard deviations, within groups covariance matrix, the within groups correlation matrix; and for each step, the variables included and F-to-remove, variables not included and F-to-enter, Wilk's Lambda (or U statistic) and approximate F statistic to test equality of gtoup means, and the matrix of F statistics to test the equality of means between each pair of groups.

A subset of this wealth of information about the data has been tabulated and will be referred to in the following paragraphs, along with comments about it significance.

Referring to the map distances in Table 1, it is seen that blue and red are the closest pair in Ch. 3 (over visual cortex), while blue and green are closest for Ch. 4.

This finding, if further validated, may lead to a demonstration of an objective measure of cortical processing of hue information in intact man. This finding could be predicted by pointing out that blue and red which are at the two extremes of the spectrum are also least similar at the eye level (Ch. 4) which in part reflects the EOG (Electrooculogram). By contrast, the nearness of blue and red over visual cortex (Ch. 3) matches the data in the CIE chromaticity diagram (Fig. 1) which was constructed from psychophysical experiments, thus probably reflecting processes occurring in the visual cortex.

Also from Table 1, referring to the 10 step classification matrices, it can be seen that SWDA did a very good job of classifying each epoch into its proper group using a D. F. based on only 10 sample variables. Ch. 3 gave the most accurate classification, with an error rate of 7.6 when operating with three groups with a misclassification rate of 8.9 . The classification matrix also provides distance information in the form of confusibility. Looking at the 10 step matrix for 3 colors, for Ch. 3 (Table 1), it is seen that green epochs are always classified as belonging to the green group, 48 out of 48, while 44 red epochs were correctly classified as red, none as green, and 4 were classified as blue. Also, 7 epochs of blue were incorrectly classified as red, none as green, and 40 were correctly placed in the blue column. These results imply that red and blue are closer than either red and green or blue and green in these data, since they are more often confused, i.e. incorrectly classified as each other by the program.

A. Channel-Wise Comparisons (Table 1)

1) As expected, with the data, Channel 3 gave the best discrimination followed by Channels 4, 2 and 1 respectively.

2) Channels 1 and 2 chose similar initial variables to discriminate between the different color groups.

3) The time points around 26, 29, 30, 33, 41, 45, 61, and 69 seemed to predominate the classification functions computed for the various channels from the raw data.

B. Color-Wise Comparisons

I. Red (Table 3 run A-9, Table 4 runs A-8, A-12a

1) Red color data is easily separable.

2) Using the Channel 3 runs (10, 16, 18) we see that time points around: 21, 29, 33, 36, 46 predominate.

3) We also note that time point 29 occurs in all the three runs indicating that time point 29 definitely is associated with a red color component.

4) Overall, time points 21, 29 and 33 can be attributed to the color red.

II. Green (Table 3 run A-12, Table 4 runs A-12a, A-7)

1) Green color seems to be easily distinguishable by SWDA.

2) Using Channel 3 runs (12, 18, 20) we see that time points around: 10, 20, 28, 41, 45, 64, 73 seem to dominate.

3) Overall, time points 28, 45 could be attributed to the color green.

III. Blue (Table 3 run A-11, Table 4 runs A-8, A-7)

1) Using the Channel 3 runs we find that time points around: 18, 21, 22, 24, 33, 37, 41, 79 seen to dominate.

2) Time point 22, 38 gives us a hint of the color blue.

C. Inter Color Qualifications

I. Red vs Green (Tables 3 and 4 runs A-9, A-12, A-12a)

Using Channel 3 we see that time points around: 10, 20, 29, 33, 34, 36, 40, 64, 73 dominate.

II. Green vs Blue (Tables 3 and 4 runs A-12, A-11, A-7)

Using Channel 3 we see that time points around: 10, 20, 33, 34, 37, 41, 45, 64 dominate.

III. Red vs Blue (Tables 3 and 4 runs A-9, A-11, A-8)

Using Channel 3 we find that time points around: 20, 26, 29 33, 34 dominate.

To answer the question as to how good the classification functions produced by SWDA are, a special run was made. The data used were from Chennel 3 (raw). The Red, Green and Blue groups were each split in two groups, and the classification functions produced by the program based on the first half of the data were used to classify the second half. The classification matrices at steps 1, 5 and 10 are given in Table 5.

We see that the classification functions produced by the program provide a good discrimination (86 vs 93 overall) on color evoked responses. This provided encouragement toward the use of the classification functions on-line in subsequent experiments.

TABLE #1

RUN CODE*	CHANNEL	GROUP NAMES GR 1 vs GR 2	MAP DISTANCE (INCHES)	GROUP	CLASSIFICATION MATRICES								
					STEP I			STEP 5			STEP 10		
					Red	Grn	Blu	Red	Grn	Blu	Red	Grn	Blu
A-18	Channel 1	Red vs Grn	4.10	Red	32	9	7	36	3	9	35	4	9
		Red vs Blue	2.30	Grn	8	34	6	5	36	7	4	42	2
		Grn vs Blue	3.25	Blu	22	19	6	7	7	33	8	3	36
A-15	Channel 2	Red vs Grn	4.30	Red	30	4	14	34	3	11	41	3	4
		Red vs Blue	3.15	Grn	3	32	13	2	39	7	3	41	4
		Grn vs Blue	2.80	Blu	13	16	18	11	8	28	4	7	36
A-3	Channel 3	Red vs Grn	5.10	Red	17	12	19	41	0	7	44	0	4
		Red vs Blue	3.50	Grn	11	36	1	1	46	1	0	48	0
		Grn vs Blue	5.00	Blu	9	3	35	5	1	41	7	0	40
A-1	Channel 4	Red vs Grn	4.10	Red	43	5	0	45	0	3	45	1	2
		Red vs Blue	4.90	Grn	7	17	24	2	38	8	1	41	6
		Grn vs Blue	2.50	Blu	5	19	23	2	8	37	1	5	41
A-9	Channel 3 (Red vs Non-Red)	Red vs Non-Red	3.10	Red	23	25		45	3		45	3	
				Non-Red	9	86		11	84		6	89	
A-10	Channel 3 (Grn vs Non-Grn)	Grn vs Non-Grn	4.30	Grn	32	16		48	0		48	0	
				Non-Grn	10	85		0	95		0	95	
A-11	Channel 3 (Blu vs Non-Blu)	Blue vs Non-Blue	4.10	Blu	30	17		36	11		42	5	
				Non-Blu	14	82		6	90		2	94	
A-8	Channel 3 (Red vs Grn)	Red vs Grn	4.30	Red	38	10		48	0		48	0	
				Grn	10	38		1	47		0	48	
A-12a	Channel 3 (Red vs Blue)	Red vs Blue	3.70	Red	33	15		44	4		48	0	
				Blu	18	29		6	41		2	45	
A-7	Channel 3 (Green vs Blue)	Grn vs Blue	4.30	Grn	42	6		48	0		48	0	
				Blu	7	40		0	47		0	47	

*RUNCODE - Refer to runs identified with this code; summaries are compiled in the later part of this report.

CHANNEL WISE COMPARISONS TABLE #2

***Indicates 90.0% or over

RUN CODE*	DATA DESCRIPTION	GROUPS/# CASES	CORRECT CLASSIFICATION PERCENTAGE ACHIEVED	# STEPS	VARIABLES CHOSEN (AFTER 10 STEPS)
	(Red vs Grn vs Blue)				
A-18	Channel 1	Red/48 vs Grn/48 vs Blue/47	81.1	9	50,69,61,41,32,30,20,36 4,40
A-15	Channel 2	Red/48 vs Grn/48 vs Blue/47	82.5	10	50,40,69,61,36,30,44,74, 65,80
A-3	Channel 3	Red/48 vs Grn/48 vs Blue/47	***	5	41,34,45,29,26,22,33,10, 68,65
A-1	Channel 4	Red/48 vs Grn/48 vs Blue/47	***	12	20,44,13,9,32,26,29,4. 12,48

*RUNCODE - Refer to runs identified by this code; summaries are compiled in the later part of this report.

VARIABLES - multiplied by 4 transforms the time points in milliseconds.

COLOR WISE COMPARISONS TABLE #3

***Indicates 90.0% or over

RUN CODE*	DATA DESCRIPTION	GROUPS/# CASES	CORRECT CLASSIFICATION PERCENTAGE ACHIEVED	# STEPS	VARIABLES CHOSEN (AFTER 10 STEPS)
A-9	Channel 3 Raw (Red vs Grn & Blue)	Red/48 vs Non Red/95	***	4	34,29,33,26,69,38,55,51, 47,36
A-12	Channel 3 Raw (Grn vs Red & Blue)	Grn/48 vs Non Grn/95	***	2	41,34,45,10,73,64,37,20, 33,28
A-11	Channel 3 Raw (Blu vs Red & Grn)	Blu/47 vs Non Blu/96	***	6	40,30,26,67,33,22,38, 24,21

*RUNCODE - Refer to runs identified by this code; summaries are compiled in the later part of this report.

VARIABLES - Multiplied by 4 transforms the time points in milliseconds.

PAIR WISE COMPARISONS TABLE #4

***Indicates 90.0% or over

RUN CODE*	DATA DESCRIPTION	GROUPS/# CASES	CORRECT CLASSIFICATION PERCENTAGE ACHIEVED	# STEPS	VARIABLES CHOSEN (AFTER 10 STEPS)
A-8	Channel 3 Raw	Red/48 vs Blu/47	***	3	29,33,26,22,79,24,21,17, 20,16
A-12a	Channel 3 Raw	Red/48 vs Grn/48	***	2	33,40,10,46,29,41,21,73, 64,36
A-7	Channel 3 Raw	Grn/48 vs Blu/47	***	2	41,34,45,10,37,64,73,80, 58,18

*RUNCODE - Refer to runs identified by this code; summaries are compiled in the later part of this report.

VARIABLES - Multiplied by 4 transforms the time points in milliseconds.

	Red	Green	Blue	Red	Green	Blue	Red	Green	Blue
Red 1	10	3	11	21	0	3	24	0	0
Green 1	4	19	1	1	23	0	0	24	0
Blue 1	7	2	15	1	0	23	0	0	24
Red 2	10	1	13	11	1	12	18	0	6
Green 2	9	14	1	0	23	1	0	24	0
Blue 2	10	2	11	4	0	19	4	0	19
		STEP 1			STEP 5			STEP 10	

TABLE 5

Refer to Run: A-2

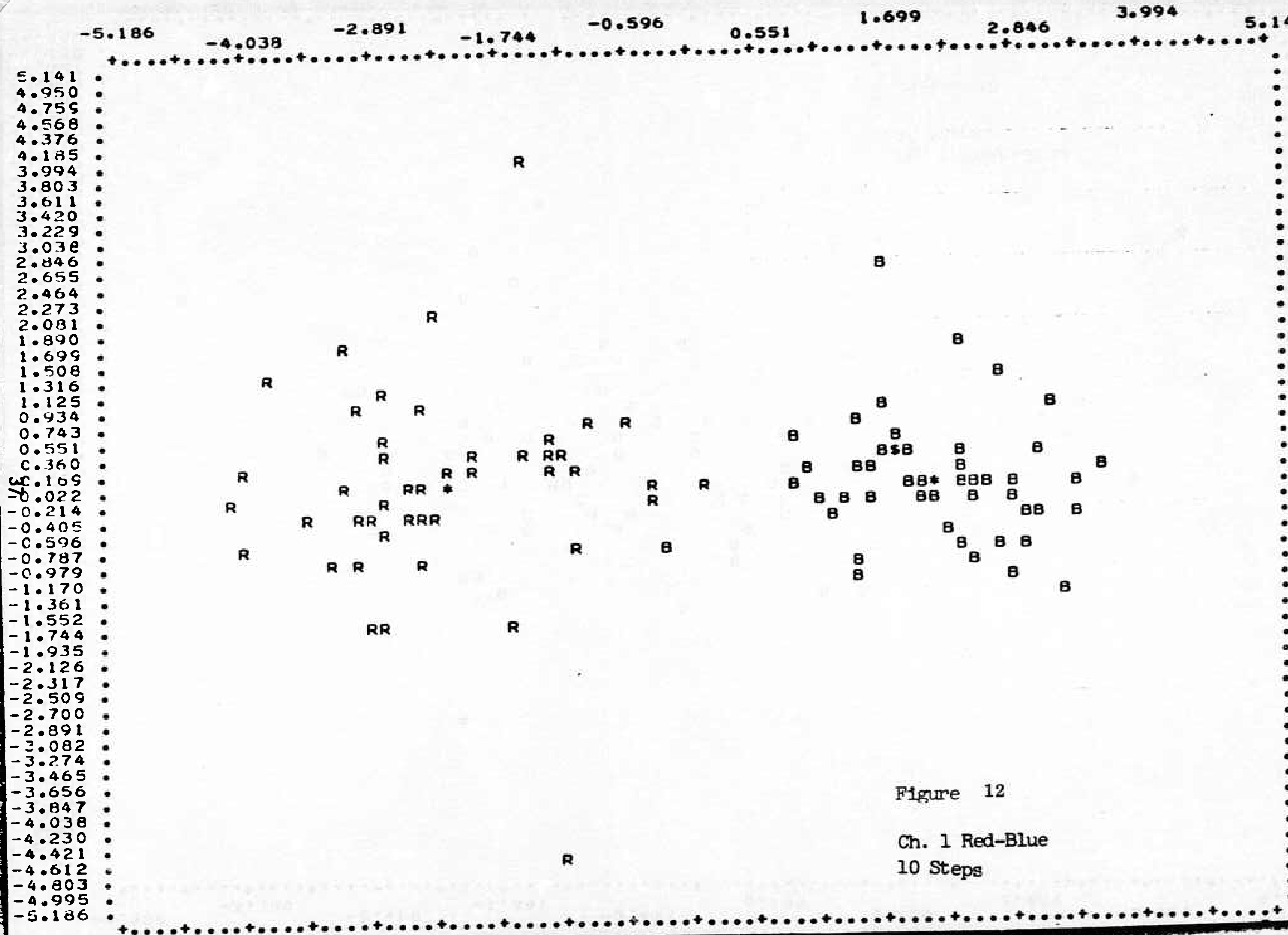
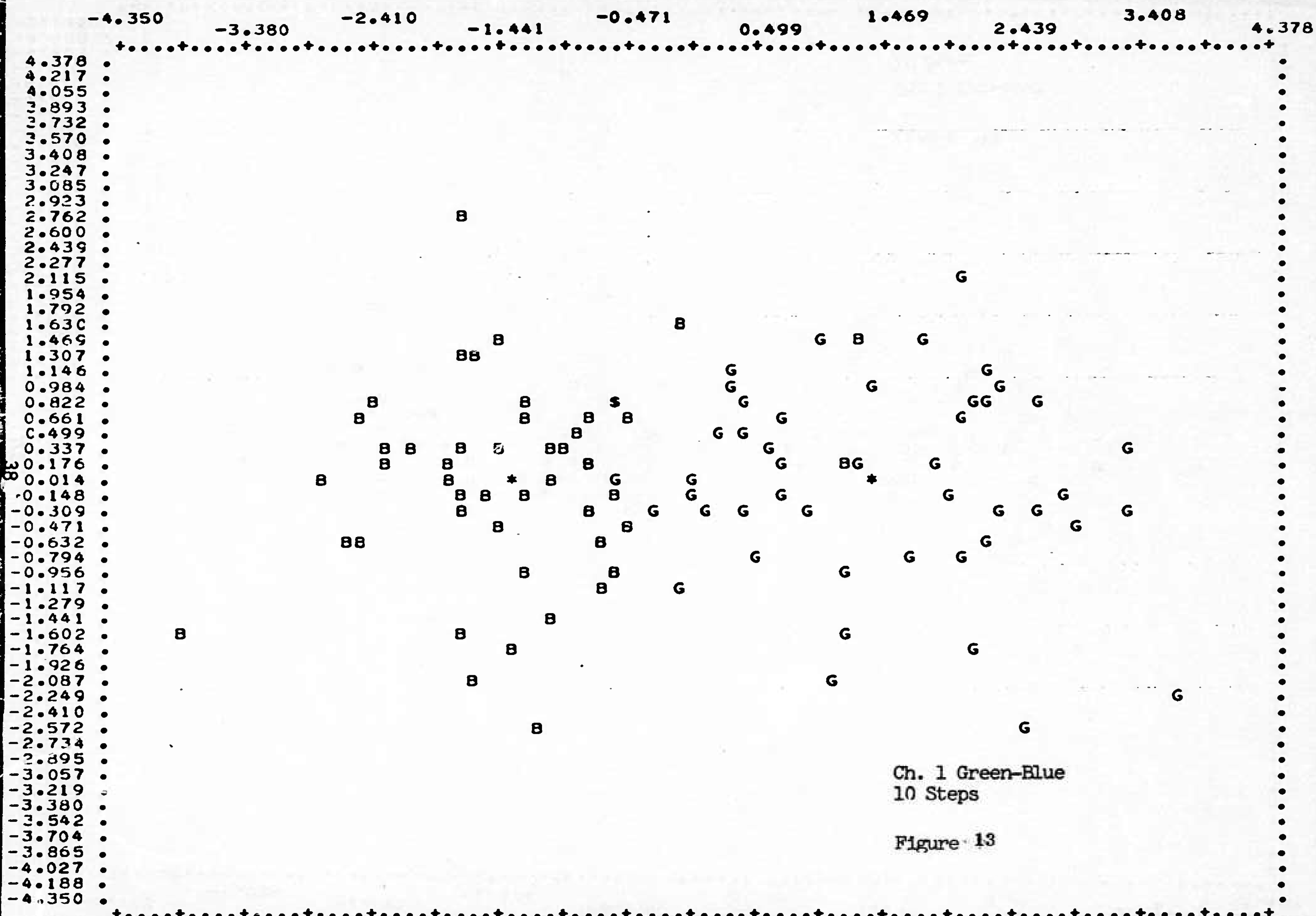


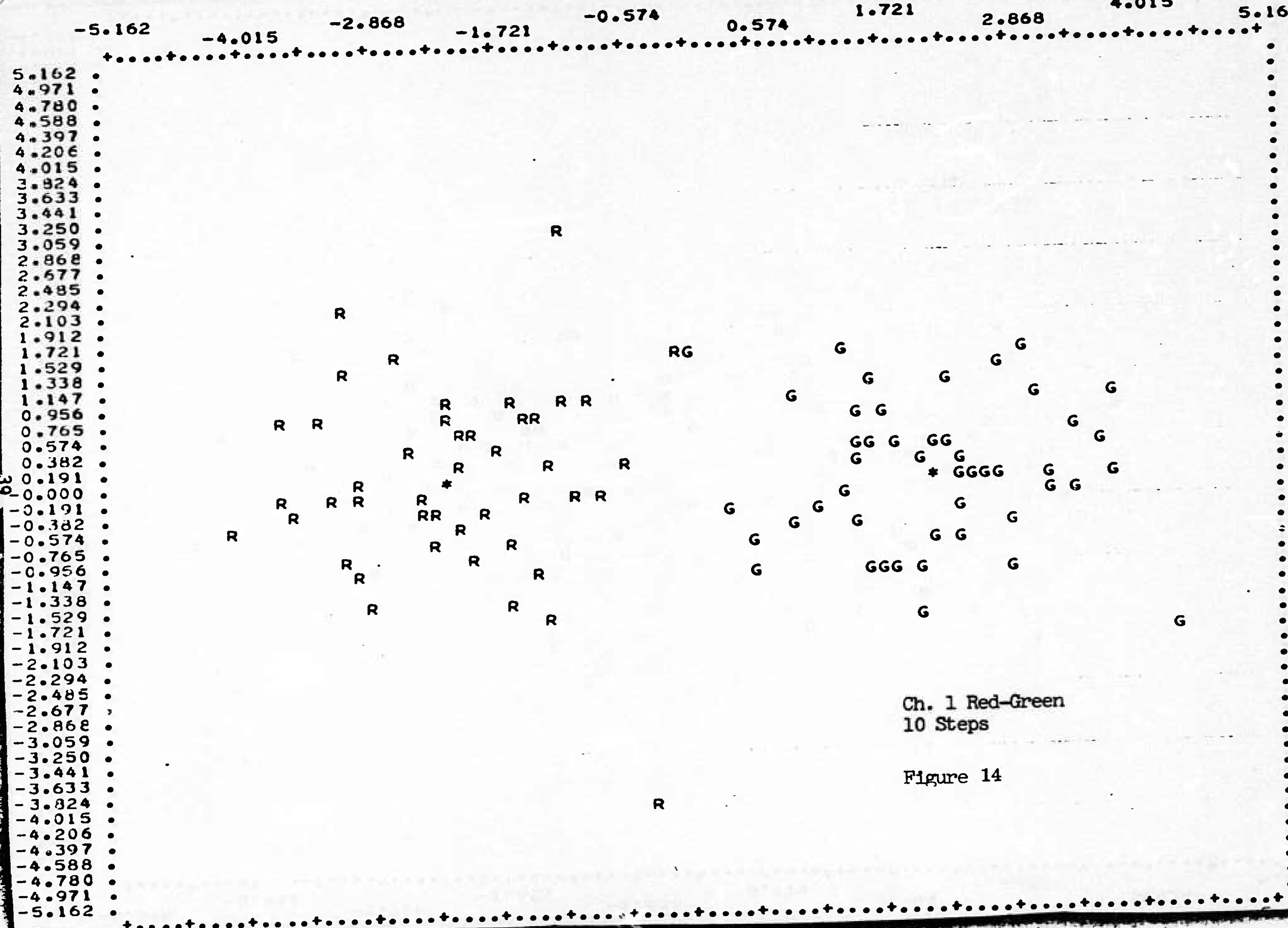
Figure 12

Ch. 1 Red-Blue
10 Steps



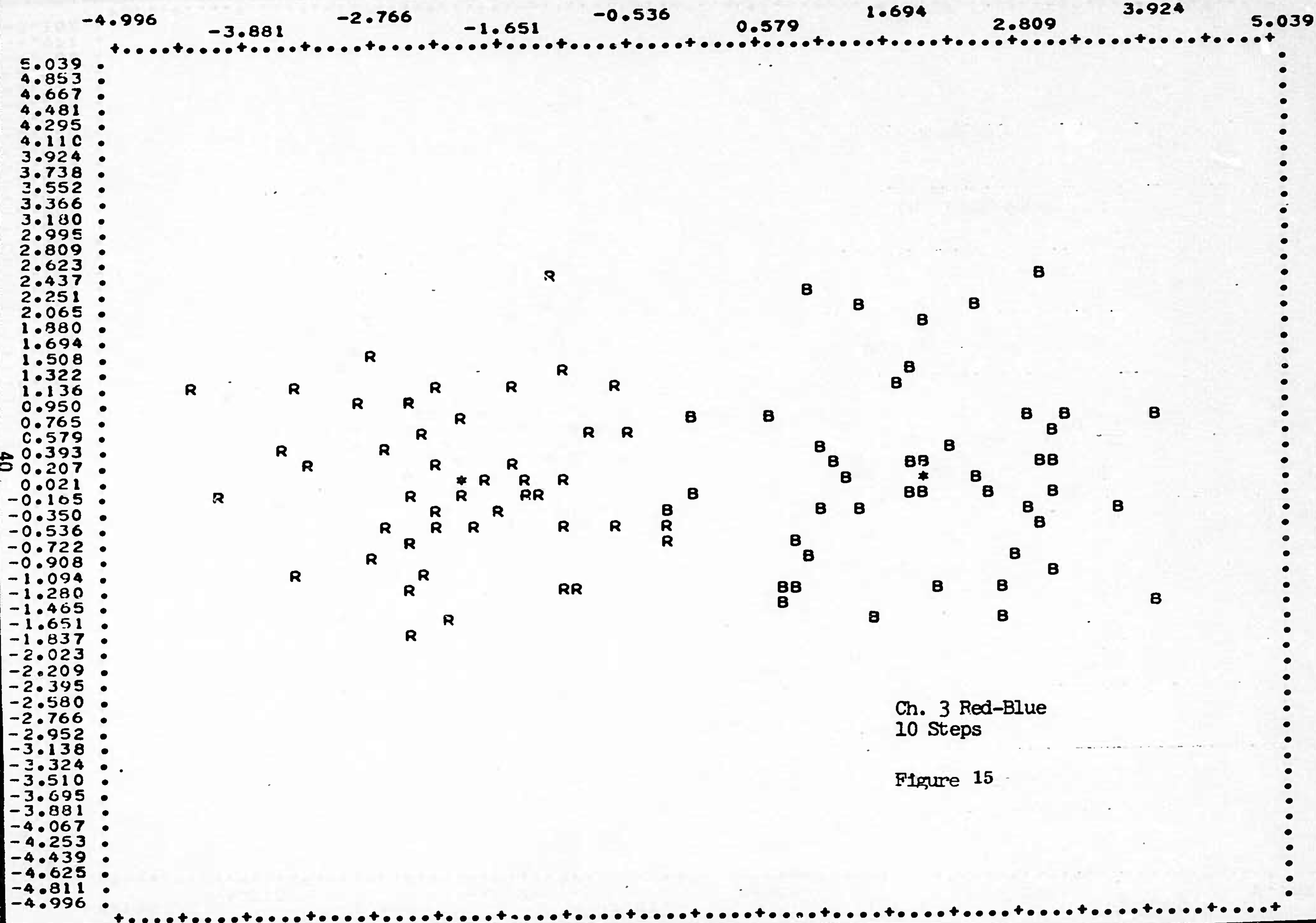
Ch. 1 Green-Blue
10 Steps

Figure 13



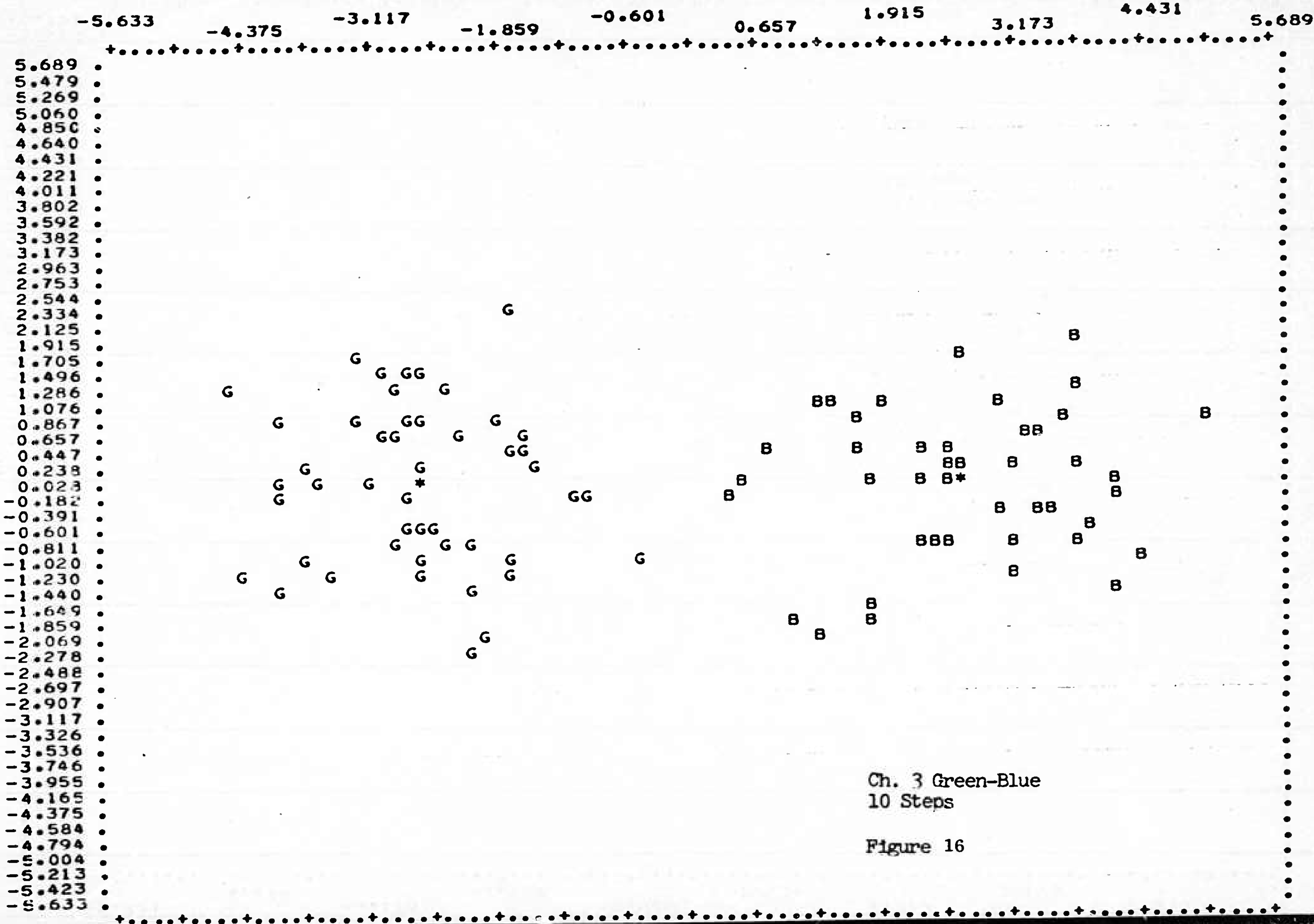
Ch. 1 Red-Green
10 Steps

Figure 14



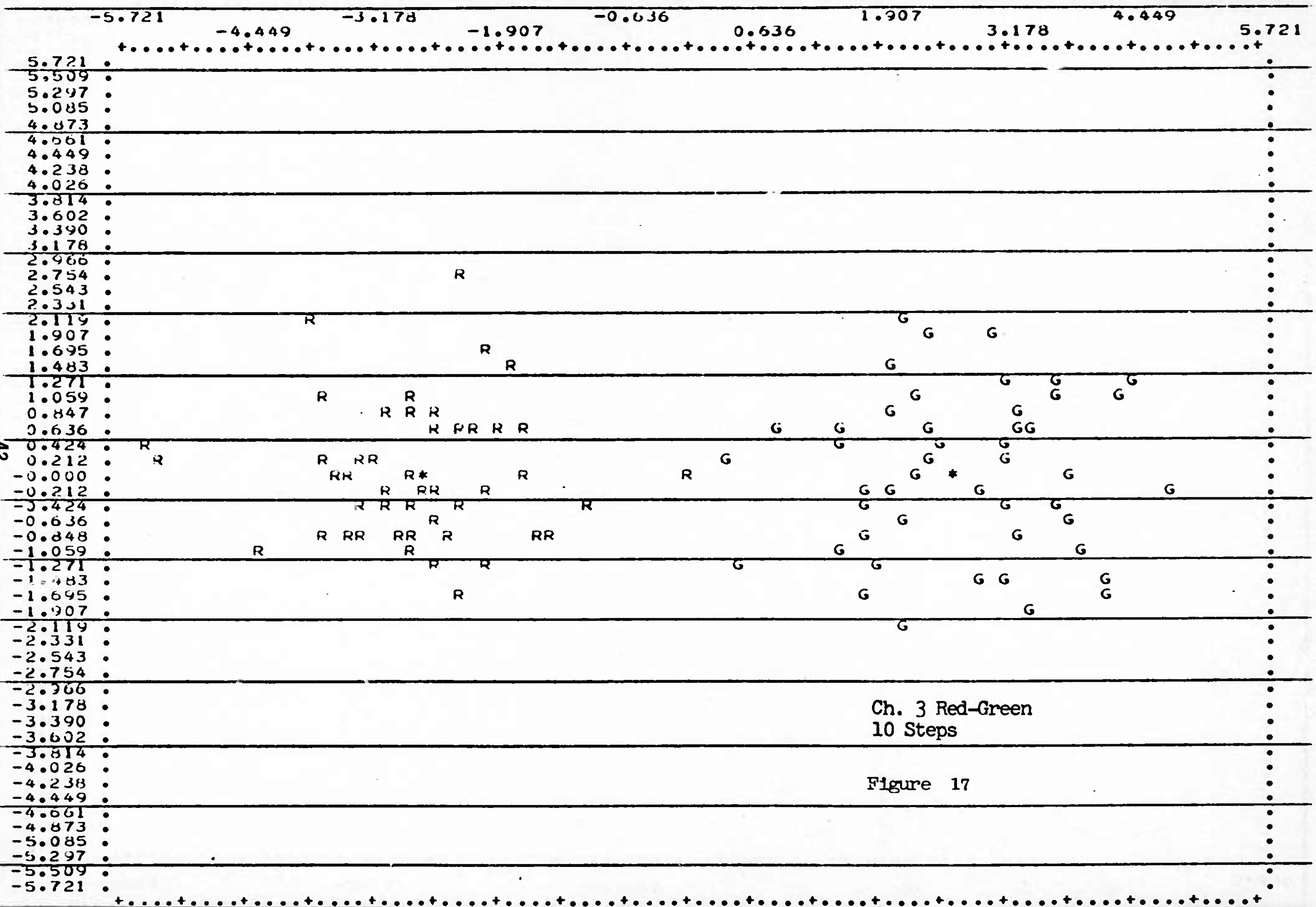
Ch. 3 Red-Blue
10 Steps

Figure 15



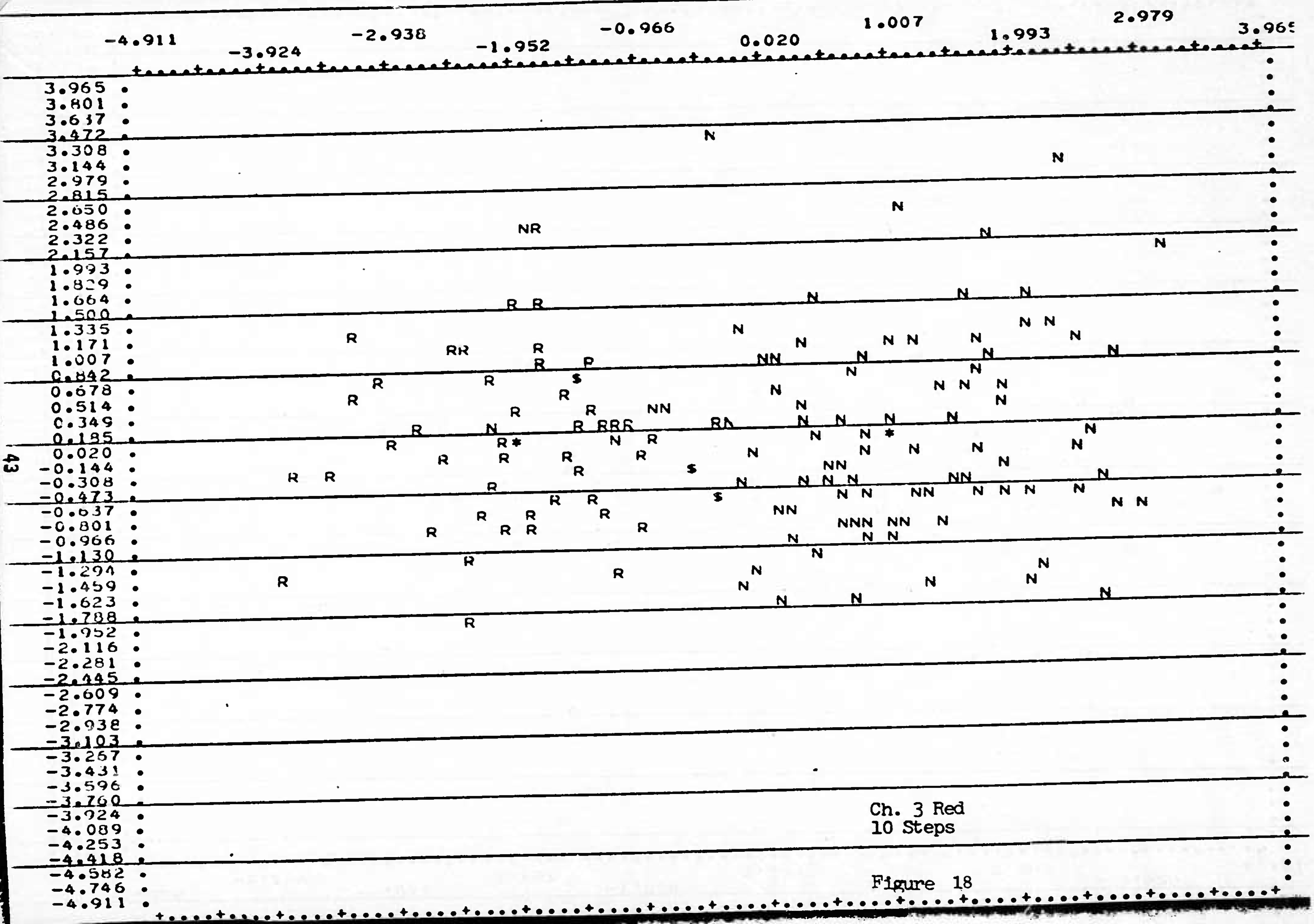
Ch. 3 Green-Blue
10 Steps

Figure 16



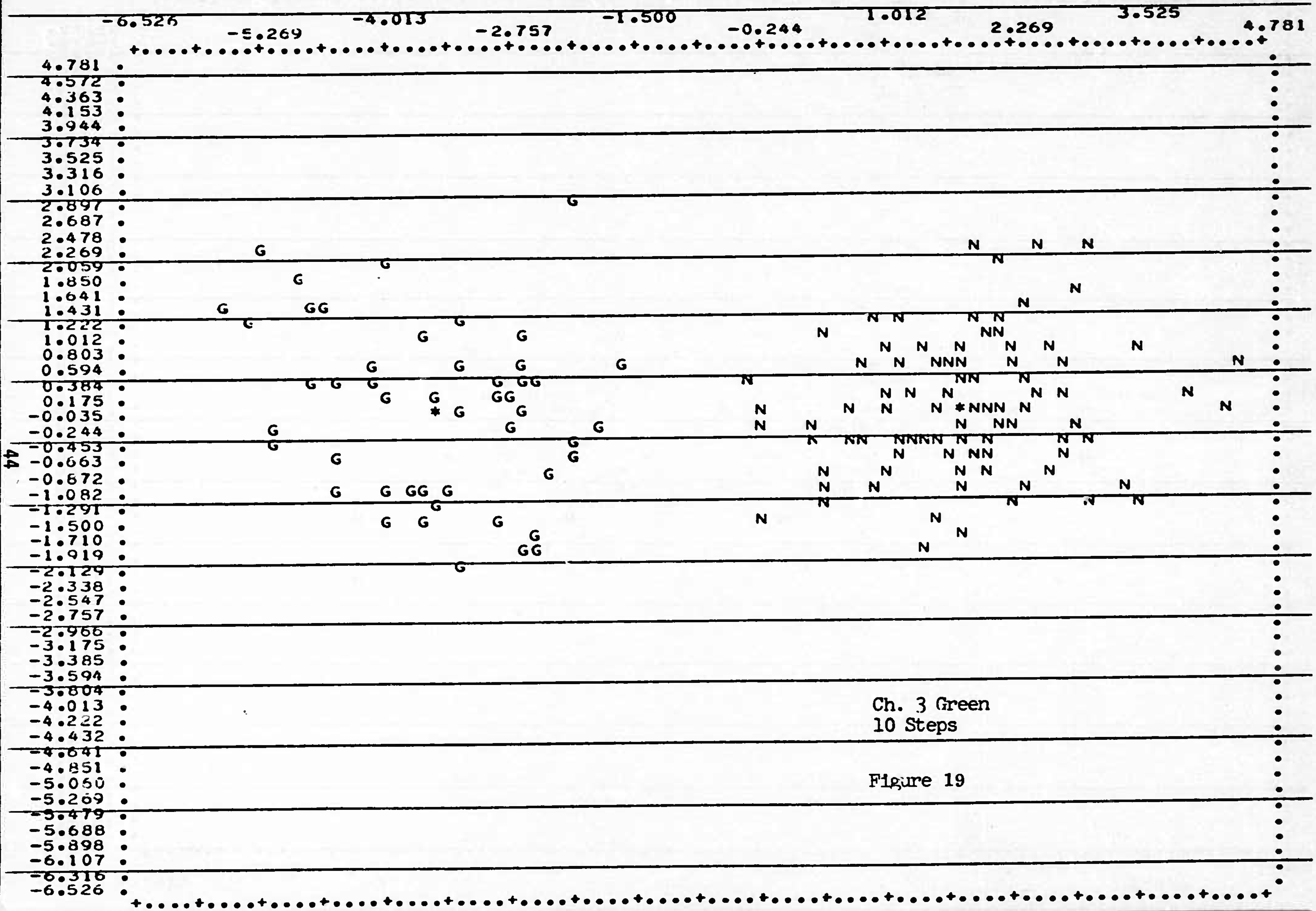
Ch. 3 Red-Green
10 Steps

Figure 17



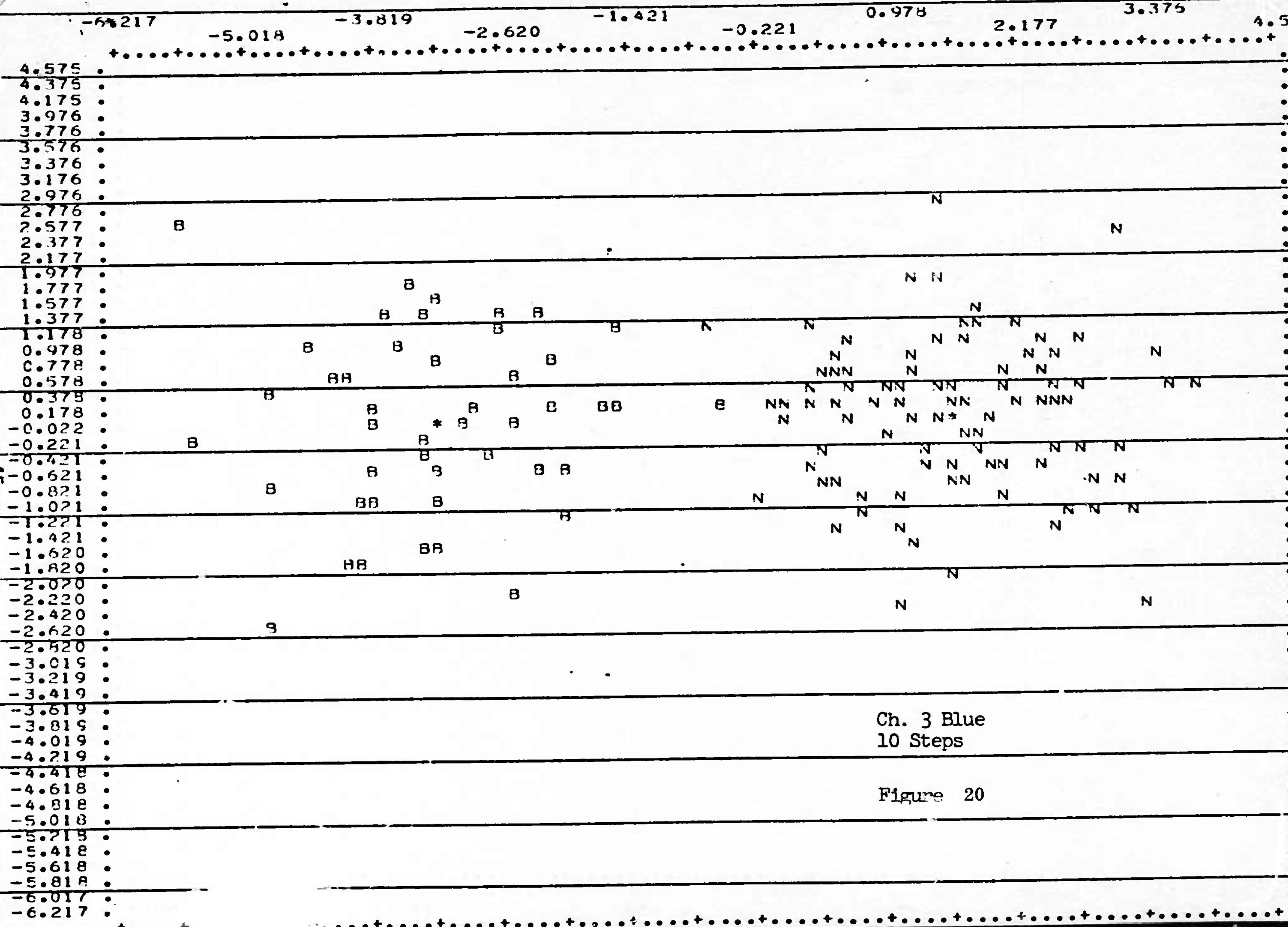
Ch. 3 Red
10 Steps

Figure 18



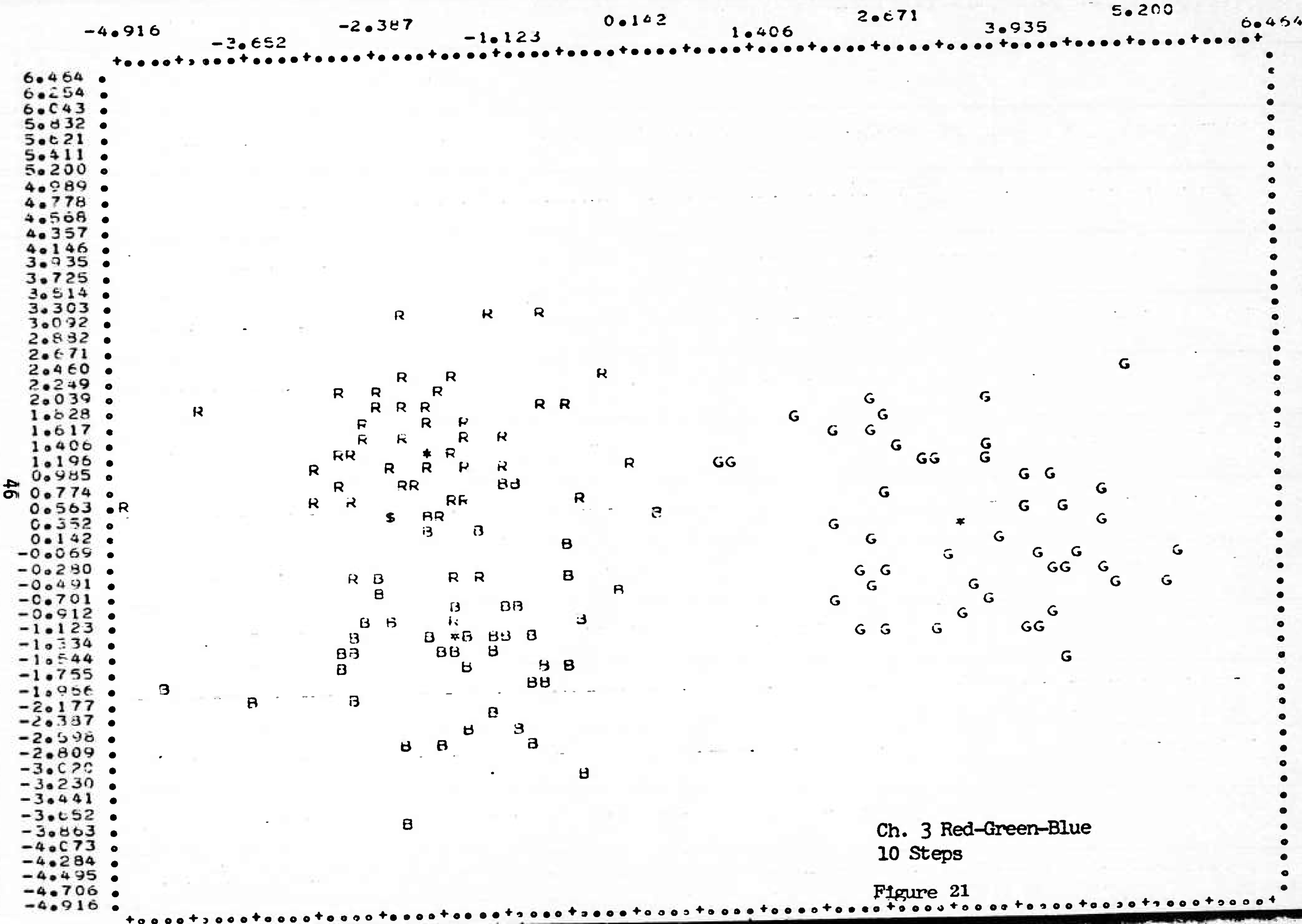
Ch. 3 Green
10 Steps

Figure 19



Ch. 3 Blue
10 Steps

Figure 20



Ch. 3 Red-Green-Blue
10 Steps

Figure 21

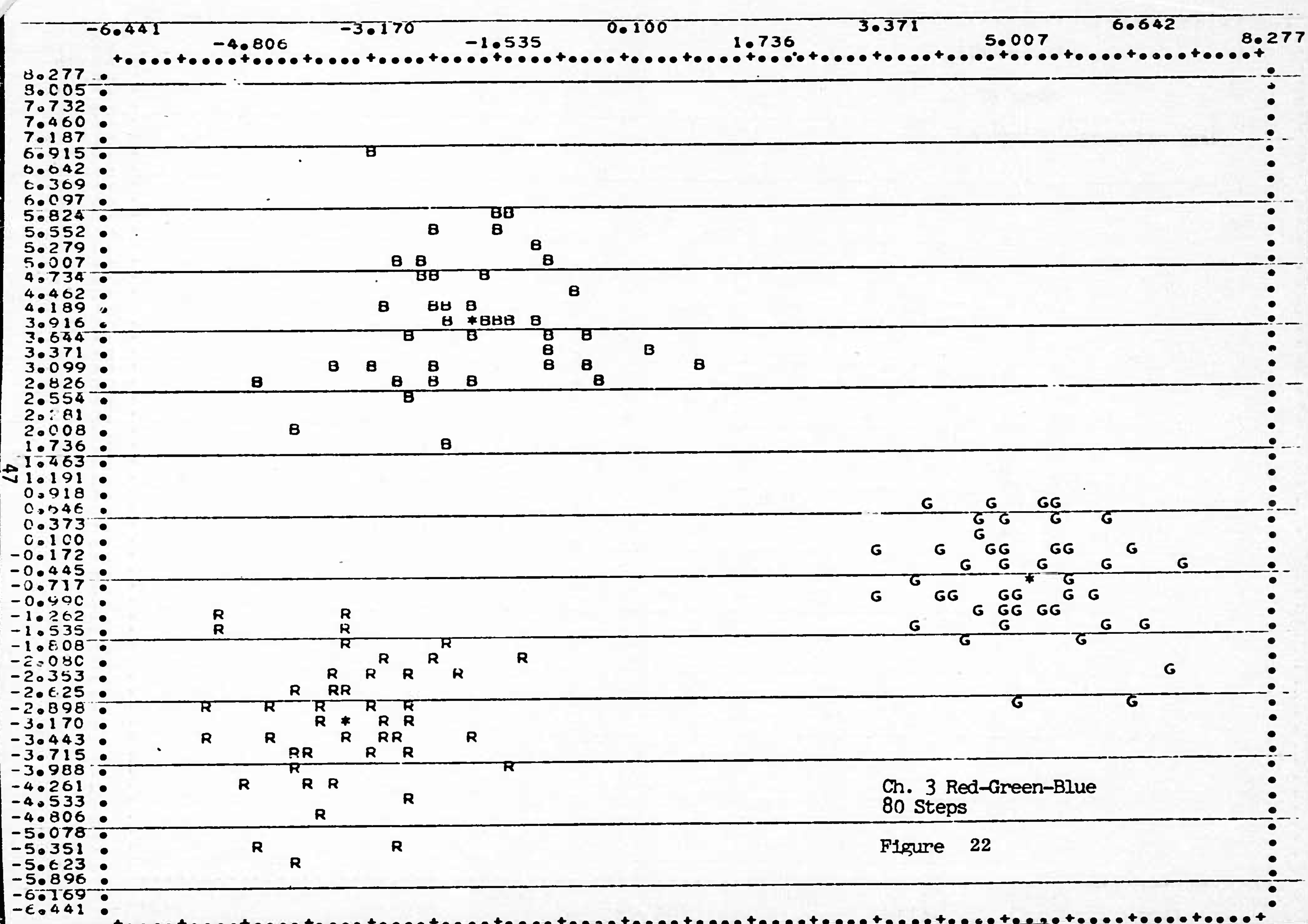
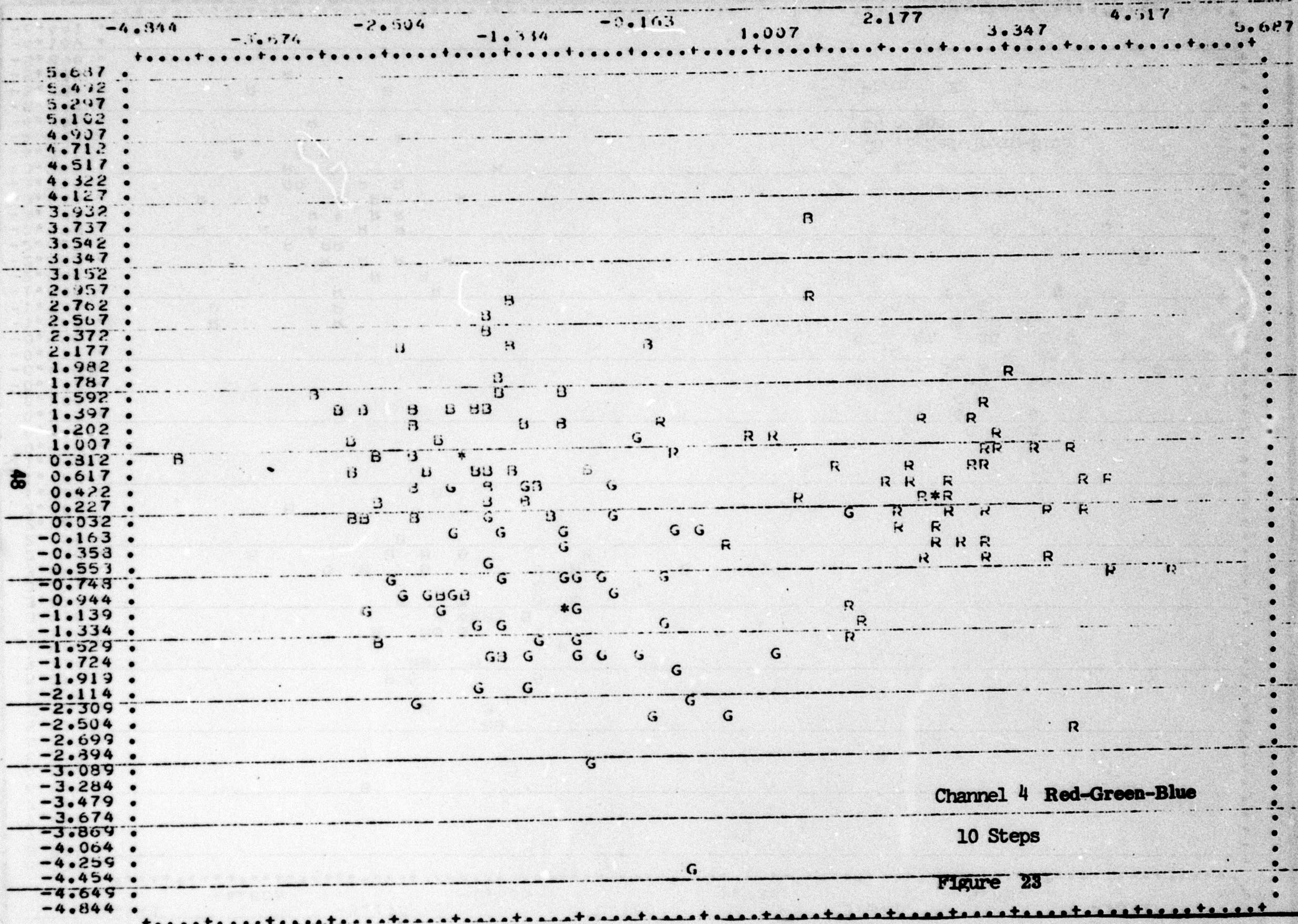

-6.441
-4.806
-3.170
-1.535
0.100
1.736
3.371
5.007
6.642
8.277
Ch. 3 Red-Green-Blue
80 Steps

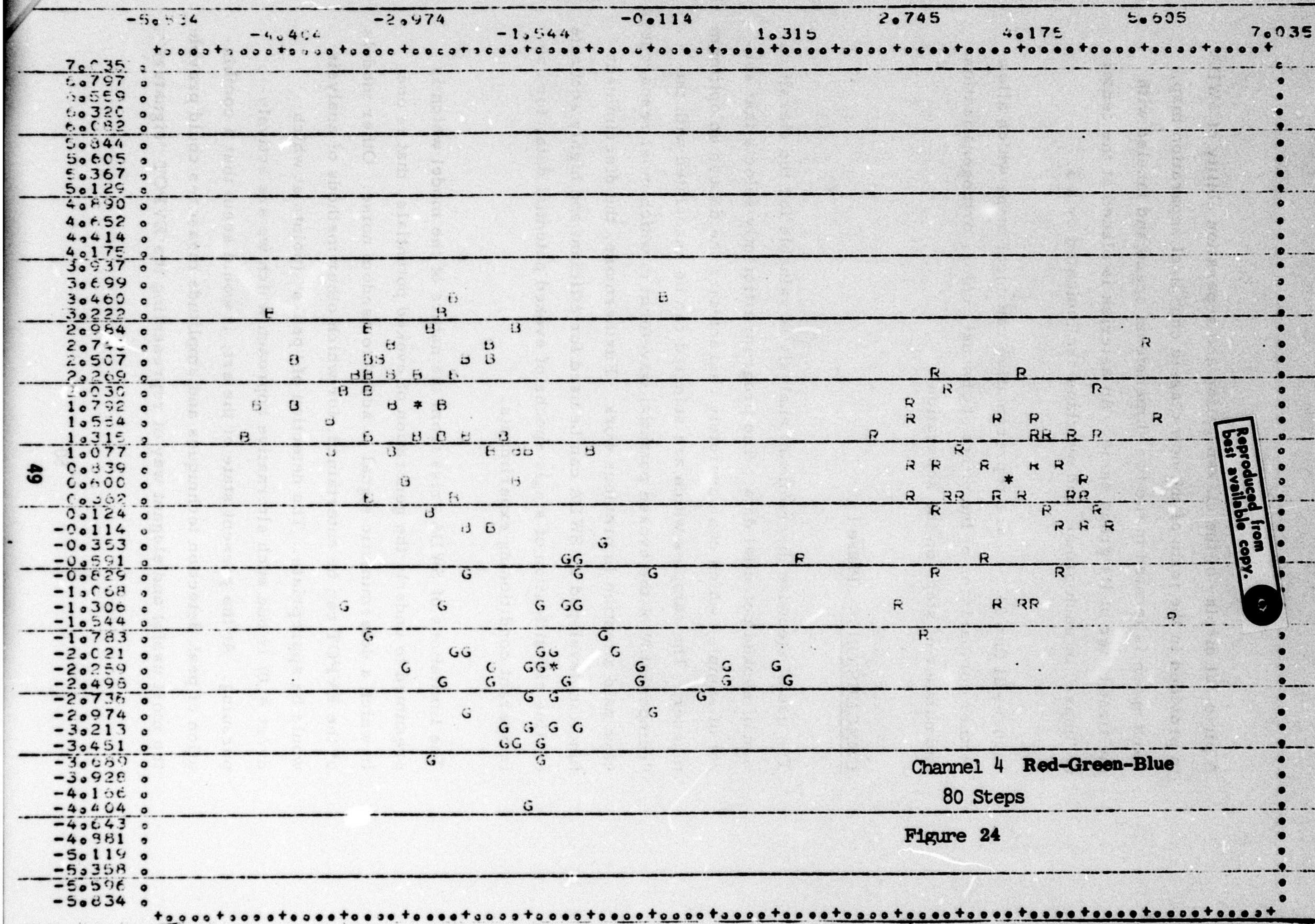
Figure 22



Channel 4 **Red-Green-Blue**

10 Steps

Figure 23



Channel 4 **Red-Green-Blue**

80 Steps

Figure 24

A pictorial display of the classification and separation ability of SWDA is provided in the form of the now classic canonical separation map. Each epoch is located in the two-dimensional space and labeled with the first letter of its group name. An asterisk is placed at the center of "mass" of each group, and overlaps are indicated by a $.

Figures 21 thru 24 are representative canonical maps which allow further comparisons of the effect of channel, color, orthogonalization and number of steps on the separation.

CONCLUSIONS: Phase I

The use of stepwise discriminant analysis is valuable for the classification of evoked potential data. The program efficiently selects that subset of samples which can accurately characterize the data in an optimum manner. The samples which are selected can be associated with the "components" of the evoked potential waveform to which most researchers have paid attention in previous work. Furthermore, the discriminant function developed by SWDA can be used for efficient and highly accurate on-line classification of single epochs of evoked potential data, for use in operant conditioning experiments.

The limitations of SWDA arise from the nature of the model which is presumed to underly the generation of evoked potentials, that is one in which a deterministic signal is added to random noise. Other models of the EVPOT can be entertained, for which other methods of analysis would be appropriate. The detection of "peaks" (points at which $dv/dt = 0$) is one such alternative approach which we are actively pursuing. At the present state of the art, it would seem that a combination of peak detection techniques and amplitude measures could provide the most useful and elegant way of representing the EVPOT "signature".

DATA ANALYSIS

PHASE 2

The search for an appropriate methodology was centered on what appeared to be "meaningful" questions relative to color evoked responses. A summary of those questions is given in Table 8 along with the run codes of the computer runs which are summarized later in the report.

The sheets in the Appendix are the condensations of the results of Stepwise Discriminant Analysis runs on data provided by basically two experiment groups. The two experiments are described below:

<u>Experiment 1</u>: <u>Ten Color Experiment</u>

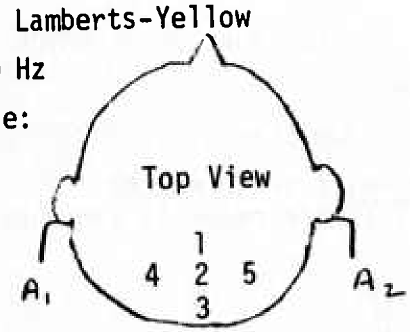
Subject: CP

Background: 250 Ft Lamberts-Yellow

EEG Channels: 1-70 Hz

Linked Ear Reference:

$A = A_1 + A_2$



Sensitivity: 2uv/mm

Sampling Rate: 4 msec.

Total Epoch Duration: 320 msec.

Stimuli were <u>non-random</u>, i.e. 64 epochs for each color stimulus were taken in sequence. For order of stimuli see Table 6

No. of Epochs per color: 64

No. of Sample Points/epoch: 80

No. of Channels: 5

Channel 1:	Top Occipital	3 cm ant to O_z/A
Channel 2:	Central Occipital	O_z/A
Channel 3:	Bottom Occipital	3 cm post. to O_z/A
Channel 4:	Left Occipital	O_1/A
Channel 5:	Right Occipital	O_2/A

In phase 2, only the data belonging to the brighter stimuli, i.e. at 0.0 log unit attenuation (namely data sets 1 through A) were processed.

This experiment was performed mainly to see the effects of spanning the whole spectrum thus obtaining a base for analysis. The approach was also a search for components associated with the three basic processes, namely, red, green and blue and for investigating of the wrap-around effects of the spectrum if present in the E.R. The experiment gave evoked responses on a large variety of colors thus providing numerous combinations to search for component codes.

Experiment 2: Opponent Color Experiment

Subject: CP

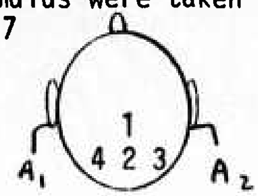
Sensitivity: 2uv/mm (Except for Purple which was 3 uv/mm)

Sampling Rate: 4 msec.

Total Epoch Duration: 320 msec

Stimuli were non-random, i.e. 50 epochs for each color stimulus were taken in sequence. For order of stimuli see Table 7

$A = A_1 + A_2$



No. of Epochs per color: 50

No. of Sample Points/Epoch: 80

No. of Channels: 5

Channel 1:	Top Occipital	3 cm ant. to O_z/A
Channel 2:	Central Occipital	O_z/A
Channel 3:	Right Occipital	O_2/A
Channel 4:	Left Occipital	O_1/A
Channel 5:	Eye	

TABLE 6 TEN COLOR EXPERIMENT

Exp. ID	Wavelength of Color in nm Filter	Color Visually Identified	Attenuation (log units)
1	420	Violet	0.0
2	465	Blue	0.0
3	490	Aqua Green	0.0
4	515	Green	0.0
5	530	Green Yellow	0.0
6	550	Yellow Green	0.0
7	575	Yellow	0.0
8	595	Orange	0.0
9	620	Red Orange	0.0
A	660	Red	0.0
11	620	Red Orange	0.5
12	595	Orange	0.5
13	575	Yellow	0.5
14	550	Yellow Green	0.5
15	530	Green Yellow	0.5
16	515	Green	0.5
17	490	Blue Green	0.5
18	465	Blue	0.5
19	530	Green Yellow	1.0

TABLE 7 **OPPONENT COLOR EXPERIMENT**

Exp. ID	Color	Attenuation	Sensitivity
502001	Blue	2.5	2uv/mm
502002	(465nm)	2.0	
502003		1.5	
502004		1.0	
502005		0.5	
502006		0.3	
502007		0.0	
502008	Yellow	2.5	
502009	(575nm)	2.0	
502010		1.5	
502011		1.0	
502012		0.5	
502013		0.3	
502014		0.0	
502015	Green	2.5	
502016	(515nm)	2.0	
502017		1.5	
502018		1.0	
502019		0.5	
502020		0.3	
502021		0.0	
502022	Red	2.5	
502023	(620nm)	2.0	
502024		1.5	
502025		1.0	
502026		0.5	
502027		0.3	
502028		0.0	
510001	Purple	0.0 to 6	3uv/mm
510002		0.3	
510003		0.5	
510004		1.0	
510005		1.5	
510006		2.0	
510007	Blue Green	2.5	2uv/mm
510008	(490nm)	2.0	
510009		1.5	
510010		1.0	
510011		0.5	
510012		0.3	
510013		0.0	
510014	White	1.8 (1+.5+.3)	
510015		1.6 (1+.5+.1)	
510016		1.5 (1+.5)	
510017		1.9 (1+.5+.3+.1)	
510018		1.7 (1+.3+.3+.1)	

TABLE 8 EXPLORATORY DATA ANALYSIS USING DATA OBTAINED FROM THE TEN AND OPPONENT COLOR EXPERIMENTS

	QUESTIONS POSED	RUNS MADE (see Appendix)
1.	Quantification of discriminability of different datum present in the early period of the epoch.	B-1
2.	Usage of multiple channels in the training and testing of DF's.	B-1, C-1, C-2
3.	Usage of a low band pass high gain filter prior to training the DF.	C-4, C-5
4.	DF trained on data from one session and tested on data from another.	D-4
5.	DF trained on data of one intensity and applied on data of higher or lower intensity.	D-13, D-14, D-15
6.	DF trained on averages and applied on raw data.	C-7, C-9, C-10, C-11,C-11a, C-8
7.	DF trained on single ER and applied on single ER.	C-1, C-2, C-3, C-4, C-8, C-12, D-4, D-6, D-7, D-8, D-9, D-10, D-11, D-12, D-19, D-21, D-22, D-23
8.	To study the variation in ER as the whole spectrum is spanned.	B-3, B-4, B-5, B-6, B-7
9.	To study the closeness of Green Green-Yellow and Yellow-Green in comparison to the extremes of the spectrum.	C-3, C-4
10.	To investigate wrap-around effects of the spectrum.	B-3, B-4, B-5, B-6, B-7, B-8, B-9, C-1, C-2, C-3, C-4, C-5
11.	To study the performance of DF trained on Red, Green and Blue ER's and applied on ER's recorded from flashes of others colors.	B-3, B-4, B-5, B 6, B-7, B-8, B-9
12.	Investigation of the discriminability of ER's obtained with opponent color pairs	D-11, D-12, D-22
13.	To study the discriminability of opponent colors of Red, Green and Blue, i.e. Blue-Green, Purple and Yellow respectively.	D-19, D-21
14.	In search for component codes by discriminating against a constant DC response.	C-13, C-13a, C-14, C-16, C-18 C-19, C-20
15.	In search for component codes by discriminating against ER's recorded for White color	D-6, D-7, D-8, D-9, D-10

QUESTIONS POSED	RUNS MADE (see Appendix)
16. To investigate the possibility of expressing ER's due to one color in terms of two others in the case of tripole of Red, Green and Blue.	C-10, C-11, C-11a
17. To evaluate the window estimated by runs associated with Red, Green and Blue colors.	D-23
18. To investigate the effect on the predictive power of DF when identified outliers are excluded from the computation of DF	D-1, D-2, D-3

The experiment was run using seven different intensity levels (from 0 log units attenuation to 2.5) for each color. A few runs were made to investigate the "goodness" of a discriminant function developed on a training set at one intensity and applying it to the testing set of another. Besides these, all other exploration was restricted to the data sets involving the brightest intensity in order to have proper comparisons with the data obtained from the ten color experiment.

We shall now go into the details of the runs made and questions asked as listed in Table 8 . The runs referred to are summarized later.

QUESTION 1; Run B-1

To investigate the amount of information contained in the early period of the epoch (i.e. right after the stimulus) reflecting the separability of the different groups.

A stepwise discriminant analysis was performed on three colors. The discriminant functions (DF) were obtained on the first 10 sample points only, i.e. the first 40 msec. of the epoch.

As we see from the run, the discriminability of the data was estimated at 47.92% and the predictive power of the DF was measured to be only 34.38%.

The poor performance is at chance level. Clearly there is very little if any information relevant to the color groups contained in the early period of the evoked response.

This confirmed data from other sources and on this basis, most of the subsequent runs were made ignoring the first 10 sample points.

QUESTION 2; Runs B-1, C-1, C-2

To investigate the possibility of determining a better performing DF by using two central occipital channels (rather than one) to train the DF. (The electrodes are one inch apart.)

The first run, B-1, was made using only the early portion of the epoch and did not give any useful information. However, C-1 was run using the Top and Central Occipital/Ears channels whereas C-2 was run using only the Top Occipital/Ears channel. In C-1, all the odd sample points were from CH1 (Top Occipital/Ears) and the even ones were from CH2 (Central Occipital/Ears).

As seen in Table 9 below there was no advantage demonstrated by using the two channels in training and testing the DF. Rather the performance remained unchanged. This may be due to the close proximity of the electrodes in which case it would suggest a lower bound for interelectrode distance. Again, this is in agreement with general working assumptions in the field.

TABLE 9 USAGE OF REDUNDANT CHANNELS IN THE TRAINING & TESTING OF DF'S

Qualified	CH1 + CH2	CH1 Only
1. Discriminability of data	93.75%	93.75%
2. Predictive Power of DF	84.88%	84.88%
3. Initial Approximate F	31.38367	31.67860
4. Variables Selected	CH1: 63,49,21, 23 CH2: 38,30,28, 44, 46.	CH1: 63, 31, 52, 45 48, 24, 21, 28, 66, 55.

QUESTION 3; Runs C-4, C-5

To study the effects of filtering on the discriminability of data and subsequent performance of the DF.

A double pole, low pass digital filter with the ability to zero mean and time varying "time constants" from Glassman's Orthogonal Derivation Program, was programmed to pre-process the data before the Stepwise Discriminant Analysis.

The data consisted of a training set of 32 epochs each of Violet, Green, Green-Yellow, Yellow-Green and Red as well as a testing set of similar contents.

Two runs were made of the Stepwise Discriminant Analysis. In one case, the data had been pre-processed by the filter and in the other the raw data was analyzed.

As a result, both the discriminability of the data (from 66% to 70%) and the predictive power of DF (from 58% to 64%) improved suggesting that filtering of the data may be beneficial. Following are the different variables (time points in msec/4) in ascending order for the two runs:

Non-Filtered: 24, 28, 30, 33, 37, 42, 46, 49, 54, 56;
Filtered: 22, 24, 25, 28, 33, 38, 45, 49, 55, 66;

Time-wise the variables selected fall in the same general neighborhoods.

Further work on applicability of the filter and optimization of the parameters was planned. The lowpass value for the filter was adjusted to match that of the EEG polygraph. The improvement is therefore attributed to a sharper drop-off of the transfer function at high frequencies.

QUESTION 4; Run D-4

To study effects of training the DF on data of one session and applying it to that of another session with the same subject.

In this run a DF was developed on 32 epochs each of Red, Green, Blue and Yellow from the Ten Color Experiment and applied on 50 epochs each of Red, Green, Blue and Yellow of the Opponent Color Experiment. This was done to investigate the validity of DF between sessions. At this the results were not very encouraging. The discriminability of data in the Ten Color Experiment was only 70.31% and the predictive power of the DF system obtained when applied on the Opponent Color data fell to 40.50%

Apparently the DF obtained was negatively affected by the introduction of Yellow data, as without it, data from the same experiment using Red, Green and Blue had yielded discriminability of 91.67% (Run D-1).

QUESTION 5; Runs D-13, D-14, D-15

To study effect of intensity on DF.

Three runs were made using different combinations of intensity:

D-13 DF trained on high intensity (0.0)
and applied on low intensity (0.3, 0.5)

D-14 DF trained on low intensity (0.3)
and applied on higher intensity (0.0) and
on lower intensity (0.5)

D-15 DF trained on low intensity (0.5)
and applied on high intensity (0.3) and
higher intensity (0.0)

TABLE 10 QUANTIFICATION (percentages) OF DISCRIMINABILITY OF DATA (diagonal) AND PREDICTIVE POWER OF DF (non-diagonal)

Training/testing Intensity / Intensity	0.0	0.3	0.5
(Brightest)0.0	86	55	30
0.3	46	83	49
0.5	31	51	57

Therefore 1) The discriminability of data degrades as the intensity of stimulus decreases as would be predicted by considerations of signal-to-noise ratio. 2) The discriminant function are intensity-bound and do not generalize. This is not surprising since the DF primitives are time-samples. Intensity changes are likely to bring about significant changes in latency that would invalidate the selection from one level to another. 3) The predictive power of a DF obtained from data of higher intensity and applied on data from lower intensity is greater than the predictive power of a DF obtained vice versa. This again ties up with the signal-to-noise ratio hypothesis.

QUESTION 6; Runs: C-7, C-8, C-9, C-10, C-11, C-11a

Effectiveness of averaged data to train the D.F. as opposed to raw data.

These runs were made in an effort to explore the advantages, if any, to be gained by using short averages of E.R. data to train a D.F.

The reasoning behind this was the standard assumption that averaging will eliminate irrelevant individual characteristics of single epoch evoked responses. As a D.F. System characterizes the aggregrate similarities within groups and aggregrate differences between groups, individual fluctuations in single evoked responses may be reduced to advantage before calculating the D.F.

A data set comprising 60 epochs each of Red, Green and Blue was used in runs C-8 and C-9. The averages were limited to 6 epochs each, thus giving a total of only 10 A.E.R.'s (averaged evoked response) per color.

Several combinations such as training on averages and testing on raw data were tried and the results are summarized below. The regularity of the averages led to perfect discrimination of the training set. Testing revealed a moderate but definite advantage. This approach deserves further study to determine an optimal trade-off.

TABLE 11 ADVANTAGES OF USING A.E.R. TO TRAIN A D.F. SYSTEM TO APPLY ON SINGLE E.R.

	R	G	B	
R	29	1	0	
G	4	26	0	90.00%
B	3	1	26	
R^2	24	4	2	
G^2	5	21	4	63.33%
B^2	9	9	12	

C-8

(Trained on raw; Applied on raw)

	R	G	B	
R	10	0	0	
G	0	10	0	100.00%
B	0	0	10	
R^2	22	7	1	
G^2	5	15	7	70.00%
B^2	2	2	26	

C-9

(Trained on averages; Applied on raw)

The discriminability of the data improved from 90.0% to 100.0% and the predictive power of the DF computed increased from 63.3% to 70.0%.

The marked improvement in the discriminability of the data as recognized by the program is also evident in Runs C-7, C-10, C-11, C-11a also made on short averages. Training set discriminability is perfect in every case. It is reasonable to assume that the resulting DF are also better performing although no comparison with raw DF were made here.

TABLE 12 INVESTIGATION USING RAW DATA (SINGLE EVOKED RESPONSES) TO TRAIN A DF AND ITS APPLICATION ON RAW DATA

	C-7	C-10	C-11	C-11a
Discriminability of data	100.00	100.00	100.00	100.00
Predictive Power of DF	43.33	86.66	85.00	76.66

QUESTION 7; Runs: C-1, C-2, C-3, C-4, C-8, C-12, D-4, D-6, D-7, D-8, D-9, D-10, D-11, D-12, D-21, D-22, D-23

D.F. trained on single E.R. and applied on single E.R.

TABLE 13 PERFORMANCE OF D.F. OBTAINED WITH RAW (SINGLE E.R.) AND APPLIED ON RAW

Run Code	Discriminability of Data (%)	Predictive Power of DF (%)
C-1	93.75	84.88
C-2	93.75	84.88
C-3	69.38	66.88
C-4	66.25	57.50
C-8	90.00	63.33
C-12	80.00	50.00
D-4	70.31	40.50
D-6	98.00	86.00
D-7	94.00	74.00
D-8	100.00	92.00
D-9	100.00	86.00
D-10	100.00	90.00
D-11	100.00	86.00
D-12	98.00	86.00
D-19	90.67	73.33
D-21	91.67	77.08
D-22	98.00	78.00
D-23	78.67	64.00

The runs listed in Table 13 were made for evaluating several different hypotheses; however, they are all examples of training a D.F. system on single E.R.'s followed by application on single E.R.'s

The discriminability of the data, as shown ranges from 66.25% to 100.00%, whereas the predictive power of D.F. varies from 40.58% to 92.00%. Run D-4 was found questionable and discarded. The percentages indicated here are not all comparable as they refer to experiments with different input sets. (They have since been replaced by a standardized measure of mutual information). The technique is clearly quite worthy of consideration. Yet, training a D.F. on short averaged E.R. could prove to be more efficient.

QUESTION 8; Runs: B-3, B-4, B-5, B-6, B-7

Investigation of variation in E.R. as the whole spectrum is spanned with five occipital channels.

TABLE 14 DISCRIMINABILITY OF E.R. FOR WHOLE SPECTRUM AS RECORDED BY DIFFERENT CHANNELS

ID	Color	Wavelength(nm)	% Discriminability of Data (5 Channels) Top	Central	Bottom	Left	Right
1.	Violet	420	69	70	72	63	61
2.	Blue	465	42	53	31	17	28
3.	Aqua	490	41	52	38	38	17
4.	Green	515	55	36	6	41	34
5.	Green Yellow	530	53	42	25	20	48
6.	Yellow Green	550	27	13	20	13	19
7.	Yellow	575	44	50	31	27	13
8.	Orange	595	25	45	8	31	16
9.	Red Orange	620	45	64	41	52	48
10.	Red	660	77	73	45	59	50
Overall discriminability recorded by each channel (%)			47.66	50.16	31.72	35.94	34.06

As we note in Table 14 the two channels, Top and Central Occipital/Ears saw the most discriminability in the data. We also find that Yellow-Green (#6) was the least discriminable color. Most of the epochs recorded for that group were confused to be from all the rest of the group.

The underlined percentages in Table 14 show that using the whole spectrum data, the extremes are the most discernable.

The channel which recorded the most discriminability for violet was Bottom Occipital/Ears, whereas Red was most clearly seen by Top Occipital/Ears.

We should note that the closeness of the groups, especially groups 3 to 7 and the large amounts of data (64 ER's per group) had a large effect in the final discriminability of data.

QUESTION 9; Runs: C-3, C-4

To study the closeness of Green, Green-Yellow and Yellow-Green in comparison to the extremes of the spectrum.

The runs B-3, B-4, B-5, B-6, B-7 showed us that responses recorded for groups 4,5,6 were very much similar (also see Question 8). This prompted a run to study these groups in comparison to the extremes of the spectrum.

From this run we see that on the application of DF developed on the above groups, 4, 5, and 6 do show higher discriminability when considered by themselves; however, group 6 is more like group 4.

QUESTION 10; Runs: B-3, B-4, B-5, B-6, B-7, B-8, B-9
C-1, C-2, C-3, C-4, C-5

To investigate wrap-around effects of the spectrum.

Looking at results obtained from runs made on the whole spectrum led to speculation that the effect of variation in the wavelength of the stimulus resulted in a corresponding gradual variation in ER and that the extremes of the spectrum resulted in similar ER's suggesting a wrap-around effect. As we notice in Runs B-3, B-4, B-5, B-6 a large number of ER's at one end were classified as coming from the other end. The following are some such examples in Table 15.

TABLE 15 SUGGESTIONS OF A WRAP-AROUND EFFECT

Run ID	Group	Correctly Classified (%)	Discriminated as Group	Incorrectly Discriminated (%)
B-3	2	17.19	10	15.63
B-4	8	48.44	2	10.94
B-5	1	68.75	9	10.94
B-5	8	25.00	2	10.94
B-5	9	45.31	1	10.94
B-5	9	45.31	1	10.94
B-6	8	07.81	1	21.88
B-7	1	60.94	10	12.50
B-7	8	15.63	2	15.63
B-7	10	51.56	1	15.63

The incorrect classification numbers are not extremely large, but they are the next highest percentages for those individual groups and thus gain significance. As a result, runs C-1, C-2, C-3, C-4 and C-5 were made with data belonging to the extremes to see if the DF system trained on such data would incorrectly classify a significant amount of ER's by putting them into opposite camps. This did not occur and on the contrary the extreme groups were found to be well apart from each other.

QUESTION 11; Runs: B-3, B-4, B-5, B-6, B-7, B-8, B-9

To study the performance of DF trained on Red, Green and Blue ER's, and applied on ER's recorded due to the rest of the spectrum.

These runs were made to investigate the possibilities of being able to describe ER's recorded by the spectrum in terms of ER's recorded by Red, Green and Blue.

This was accomplished by training a DF system on Red, Green and Blue, and studying its performance in predicting ER's belonging to the rest of the spectrum.

By looking at the final classification matrices of Runs B-8, B-9 no obvious trends were found.

QUESTION 12; Runs: D-11, D-12, D-22

Investigation of the discriminability of E.R.'s obtained with opponent color pairs.

The following statistics were recorded when runs of opponent color pairs were made. The opponent color pairs were chosen by using the chromaticity diagram for standard source "C" (artificial daylight). (See Figure 1). The opponent color for each pair was selected by extending the line connecting the color and White to the opposite side.

Opponent Color Pair	Discriminability of Data (%)	Predictive Power of DF (%)
Red-Blue-Green	100.00	88.00
Green-Purple	98.00	78.00
Blue-Yellow	98.00	86.00

We note that while the discriminability recorded by the Stepwise Discriminant Analysis program was excellent for all these opponent color pairs, the performance of the DF system computed for the Green-Purple pair was significantly lower but still on the high side when compared to typical runs in other combinations.

Examining the sample points selected in these runs did not lead at this time to any conclusive arguments in favor of component codes of the Red, Green and Blue processes.

QUESTION 13; Runs: D-19, D-21

To study the discriminability of opponent colors of Red, Green and Blue, i.e. Blue-Green, Purple and Yellow respectively.

In conjunction with Question 12 this run was made to study the discriminability of Blue-Green, Purple and Yellow. The results were very much similar to those obtained for Red, Green and Blue. They are as follows:

Run ID	Color Tripole	Discriminability of Data (%)	Predictive Power of DF (%)
D-19	BG,P,Y	90.67	73.33
D-21	R, G, B	91.67	77.08

QUESTION 14: Runs: C-13, C-13a, C-14, C-15, C-16, C-18, C-19

Search for component codes by discriminating against a constant DC response.

The rationale behind this experiment was to compare the responses with respect to a neutral "group". The results hopefully would identify the specific time windows where the activity from individual colors was at a peak.

The following table summarizes the resulting windows in the order determined by the Stepwise Discriminant Analysis program.

TABLE 16 TIME VARIABLE DISTINCTIVES OF RED, GREEN, BLUE, YELLOW, ORANGE & VIOLET

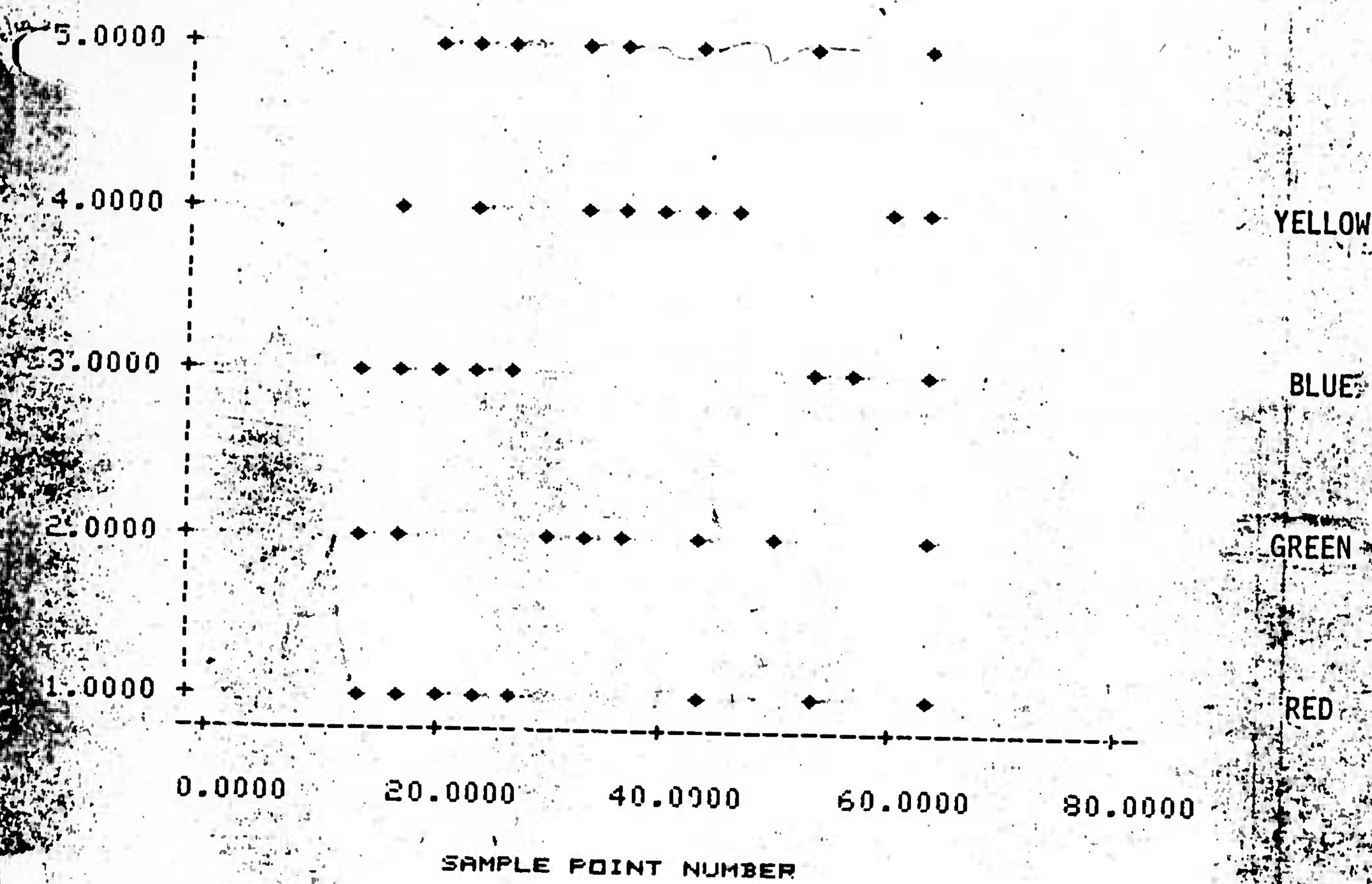
Run Code	Color	Variables
C-13a	Red	14, 20, 22, 28, 44, 25, 55, 63, 18, 15
C-14	Green	14, 17, 38, 34, 43, 50, 29, 31, 16, 64
C-16	Blue	53, 16, 63, 21, 13, 26, 27, 58, 79, 69
C-13	Yellow	25, 62, 16, 43, 60, 48, 34, 41, 37, 44
C-19	Violet	13, 35, 18, 46, 32, 11, 73, 14, 48, 65
C-18	Orange	35, 59, 12, 42, 64, 32, 13, 61, 20, 14

The adjoining Figure is a plot of the above variables in relative order for the Red, Green, Blue and Yellow colors. A wrap-around effect from Red to Blue is visible. It must be noted that only time points are considered, regardless of amplitude.

PLOT:X SX SY -?
WHAT IS THE TITLE? BCI COLOR VERSUS CONSTATN##NT
WHAT IS THE LABEL FOR THE X AXIS? SAMPLE POINT NUMBER
WHAT IS THE LABEL FOR THE Y AXIS? COO#LOR CODE
WHAT IS THE SYMBOL? ◆
WHAT IS THE LOWER LIMIT
\C FOR THE X AXIS? 1
WHAT IS THE UPPER LIMIT FOR THE X AXIS? 80
WHAT IS THE LOWER LIMIT FOR THE Y AXIS? 1
WHAT IS THE UPPER LIMIT FOR THE
\CY AXIS? 5
WHAT IS THE PAGE WIDTH IN CHARACTERS? (MUST BE AT LEAST 72) 72
DO YOU WANT THE SAME SCALE ON BOTH AXES? (YOU MUST ANSWER YES
\COR NO) NO

BCI COLOR VERSUS CONSTANT

◆ = COLOR CODE



R 1.564

Fig. 25 Discrimination Against WHITE ER's

QUESTION 15; Runs: D-6, D-7, D-8, D-9, D-10

In search for component codes by discrimination against ER's recorded for White color.

Following up some of the search strategy as in Question 14, these runs were made to compare ER's recorded for Red, Green, Blue, Yellow and Purple discriminated against a group of ER's recorded with a White flash.

TABLE 17 TIME VARIABLES CHOSEN FOR DISCRIMINATION AGAINST WHITE COLOR

Run Code	Color	Variables Chosen (in order)
D-10	Red	32, 9, 42, 49, 72, 68
D-9	Green	66, 36, 57, 26, 68, 64
D-8	Blue	54, 64, 22, 61, 33, 75
D-7	Yellow	63, 65, 72, 70, 56, 38
D-6	Purple	25, 75, 55, 24, 63, 72

The discriminability of the data was again excellent. The predictive power of DF was lower in the Yellow run which was against a Yellow background, and is also less discernable behaviorally.

A chart similar to Fig. 25 is shown in Fig. 26 where variables chosen for each color against White are plotted along with a subset of variables chosen against a constant, pointing to a fairly complex relationship.

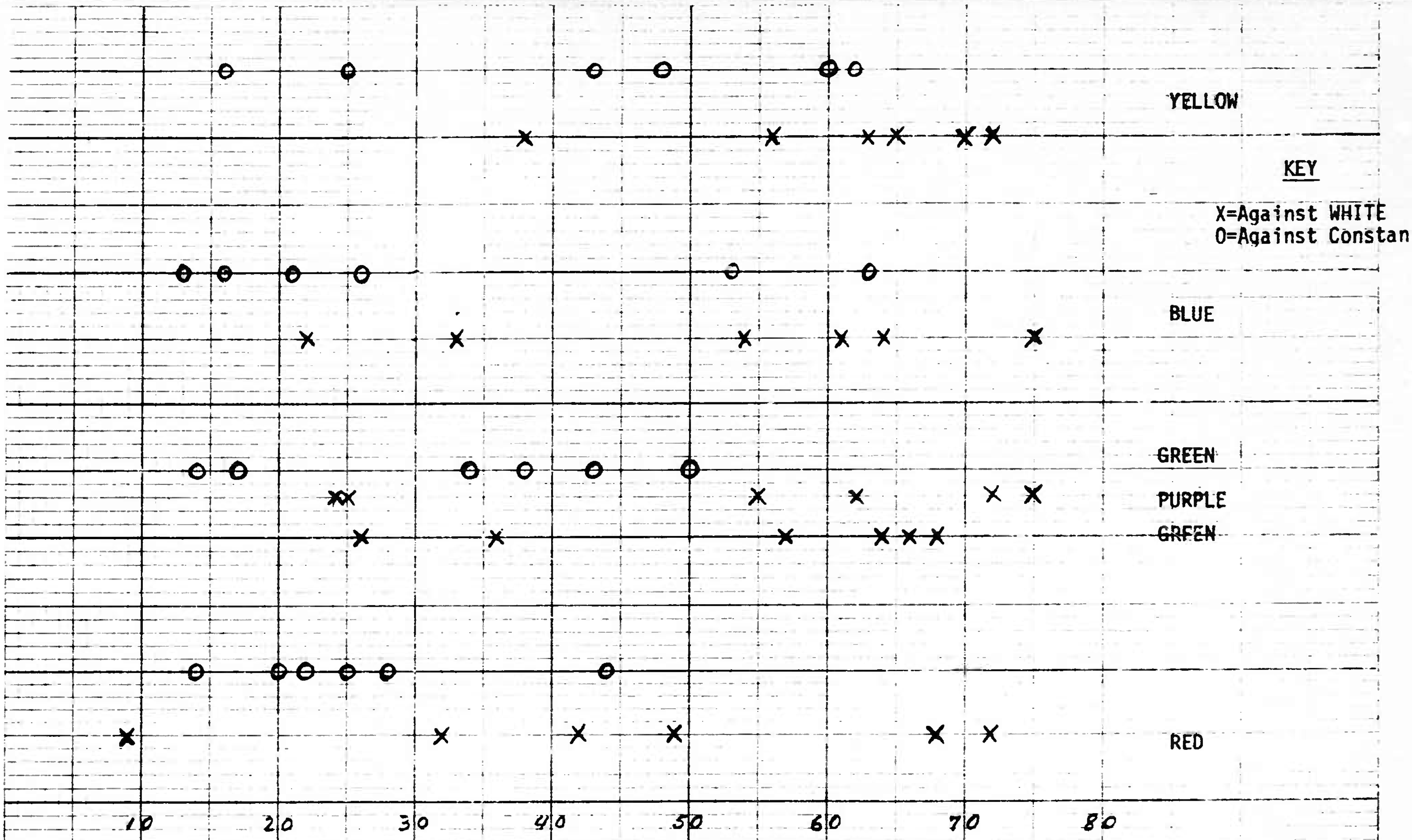


Fig. 26 Discrimination Against WHITE and against Constant DC Responses

QUESTION 16; Runs: C-10, C-11, C-11a

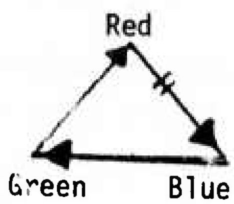
To investigate the possibility of expressing ER's due to one color in terms of the other two in the case of tripole of Red, Green and Blue.

An attempt was made to study the similarities between ER's due to the three colors namely, Red, Green and Blue. In these runs the DF was trained on the AER's from two groups and applied on AER and single ER from the third group. The results are as follows:

Run Code	Training Groups		Testing Group	Classified (%) as Group 1 All	Group 1 Raw	Group 2 All	Group 2 Raw	Final F-value
C-10	1. Red	2. Blue	Green	80	63	20	37	914.23
C-11	1. Green	2. Blue	Red	30	27	70	73	1095.90
C-11a	1. Red	2. Green	Blue	10	40	90	60	1450.26

An interesting circulating symmetry is observed as shown in Fig.

Fig. 27 DF Trained on Two Groups of Tripole and Applied on the Remaining Third



In Fig. 27 the arrow indicates the direction of the classification of of each color, given a choice between the two others used to create the DF as the table above shows. Note the unusually large final approximate F-values.

QUESTION 17; Run: D-23

To evaluate the window estimated by runs associated with Red, Green and Blue colors.

One of the most important results obtained in this phase of data analysis has been the identification of the time windows recognized by Stepwise Discriminant Analysis as containing the most information reflecting the separability of ER's recorded for the Red, Green and Blue stimuli.

Table 18 summarizes the time points selected (in msec.) in the more significant runs. A simple histogram (Fig.28) of these time points shows that most of the information seems contained in time windows around 88, 100, 116, 132 and 212 msec. taken with an aperture of ± 4 msec. This result is important because it provides us a basis for dimensionality reduction by discarding the other time points from the analysis in color discrimination. The data reduction is a precious asset to study DF's trained on multi-channel data because of the reduction in the number of variables to consider.

An evaluatory discriminant analysis run was made using the variable windows of 23-29, 34-38, 43-48 and 51-56.

As Run D-23 shows, the discriminability of data was maintained at 78.6%, and at 64% the predictive power of DF did not suffer any appreciable loss.

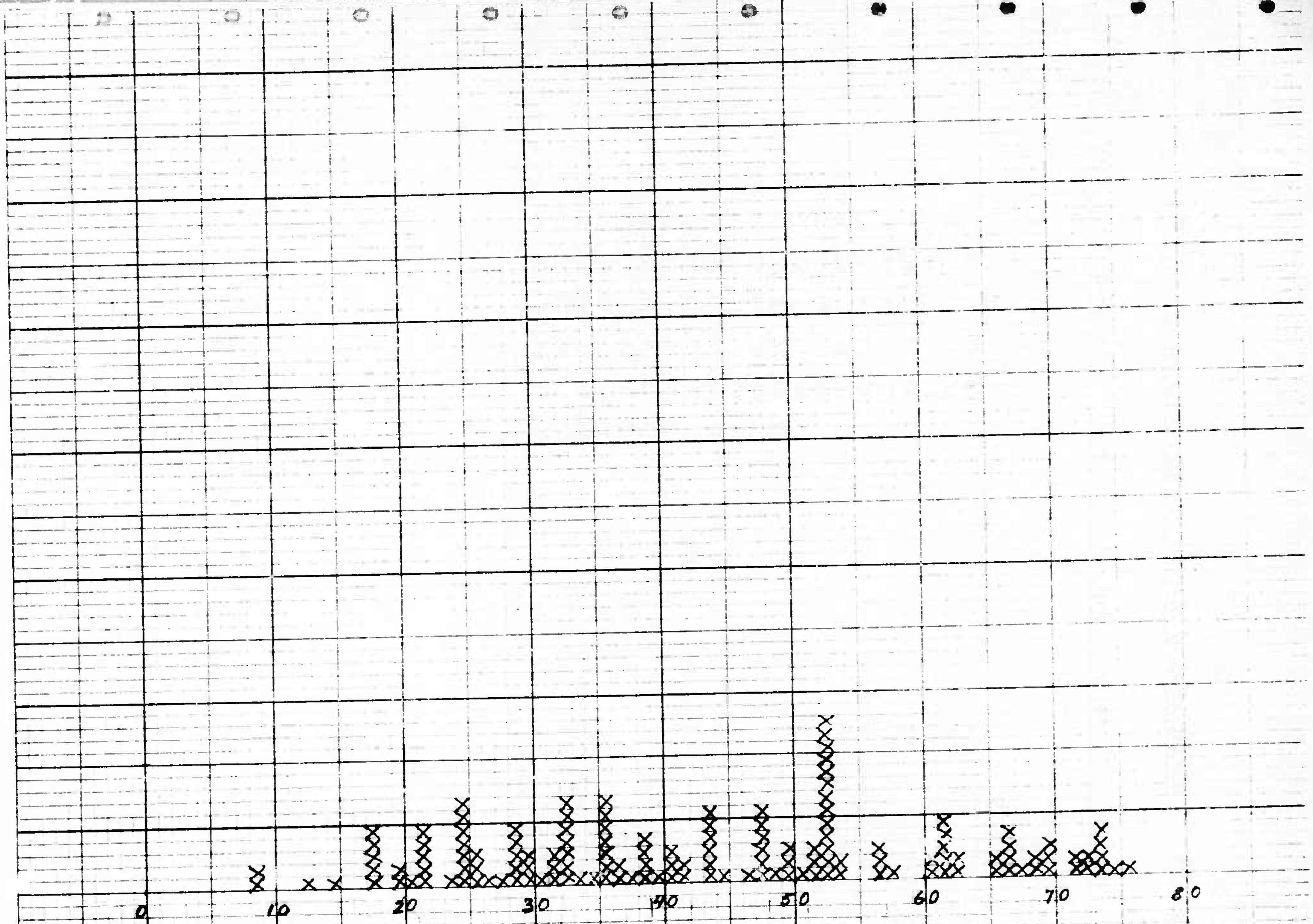


Fig. 28 HISTOGRAM OF GENERAL AREAS OF ACTIVITY FOR RED, GREEN AND BLUE STIMULI

TABLE 18 GENERAL AREAS OF ACTIVITY FOR RED, GREEN AND BLUE STIMULI

Run Code	Channel #	Exp. ID.	Variables Selected (First Six)
A-19	1	Three Color	50, 69, 61, 41, 32, 30
A-15	2		50, 40, 69, 61, 36, 30
A-3	3		41, 34, 45, 29, 26, 22
A-1	4		20, 44, 13, 9, 32, 26
B-8	1	Ten Color	53, 44, 62, 29, 67, 48
B-9	2		52, 73, 54, 35, 38, 63
C-6	1		74, 37, 39, 52, 18, 72
C-7	1		39, 37, 58, 75, 48, 57
C-8	1		74, 37, 39, 54, 72, 68
C-12	2		73, 57, 51, 9, 53, 33
D-1	1		53, 44, 62, 29, 67, 48
D-2	1		53, 44, 74, 48, 67, 62
D-3	1		53, 44, 74, 48, 42, 38
D-20	1		53, 44, 62, 29, 67, 48
D-21	1		15, 63, 53, 42, 21, 59
D-4	2		52, 20, 76, 28, 62, 25
D-5	2	Opponent Color	53, 18, 25, 36, 33, 22
D-13	2		53, 18, 25, 36, 33, 22
D-14	2		27, 53, 66, 33, 70, 24
D-15	2		30, 66, 59, 22, 33, 36
D-16	2		36, 25, 53, 32, 48, 69
D-17	2		53, 18, 25, 36, 33, 22
D-18	2		53, 31, 36, 18, 25, 50
D-19	2		25, 33, 66, 47, 26, 29

QUESTION 18; Runs: D-1, D-2, D-3

To investigate the effect on the predictive power of DF of the a priori elimination of statistical outliers from the computation of DF.

A series of three iterative runs was made to see if elimination of "outliers" (responses which were substantially outside the cluster of their group) enhanced the discriminability of data.

Table 19 below summarizes the results obtained from these runs.

ITERATIVE REJECTION OF OUTLIERS

Run Code	Iteration #	Discriminability of data (%)	Final U-statistic	Distances between means of clusters on the canonical maps (inches) Red-Green	Green-Blue	Red-Blue
D-1	0	91.67	0.084	5.229	2.641	4.25
D-2	1	95.45	0.0[illegible]8	5.987	4.201	4.902
D-3	2	100.00	0.026	6.402	4.692	5.613

It can be seen that the discriminability of data has improved considerably with each iteration. The results are illustrated in the canonical maps of the three runs. The clusters of Red, Green and Blue not only travel farther from each other, but also become more condensed.

The iterative elimination of "outliers" from the training set is now considered in the methodology. It must be noted that the variables selected in the three runs were almost identical thus giving further credence to the validity of the DF system computed.

Run Code	Variables Selected
D-1	53, 44, 62, 29, 67, 48, 38, 42, 75, 51
D-2	53, 44, 74, 48, 67, 62, 38, 42, 51, 33
D-3	53, 44, 74, 48, 42, 38, 67, 41, 62, 33

SIMULATION RUNS OF THE ORTHOGONAL DERIVATION PROGRAM

Tests Results on Ortho

The orthogonal derivation program (ORTHO) was subjected to a battery of tests on the synthetic data. Two new programs were written for that purpose. One is a general purpose PRINT-PLOT routine and the other one is a synthetic data generator (SDG). SDG was used to generate three sets of data each consisting of 3 channels with 1360 samples.

Data Set 1 (f = 4Hz)

x_1 = random noise with uniform distribution (RN)
$x_2 = x_1 + \sin(2\pi_* 4_* t)$
$x_3 = x_2$ for 1, 1280
x_2 + VER for 1281, 1360

where VER = $\sin(2\pi_* 10_* t)$

Data Set 2 (f = 4Hz)

x_1 = RN
$x_2 = x_{1*} \sin(2\pi_* 4_* t)$
$x_3 = x_2$ for 1, 1280
x_2 + VER for 1281, 1360

where VER is the same as in Data Set 1

Data Set 3 (f = 10Hz)

The same as the Data Set 1, except f = 10Hz

The tests performed were intended to answer the following questions:

a) will ORTHO separate VER from data set 1 and 2?(i.e. addition and multiplication)

b) how ORTHO behaves with changing frequency (4hz and 10Hz were used)?

c) how many samples (time) are needed for VER to get a good separation from VER?

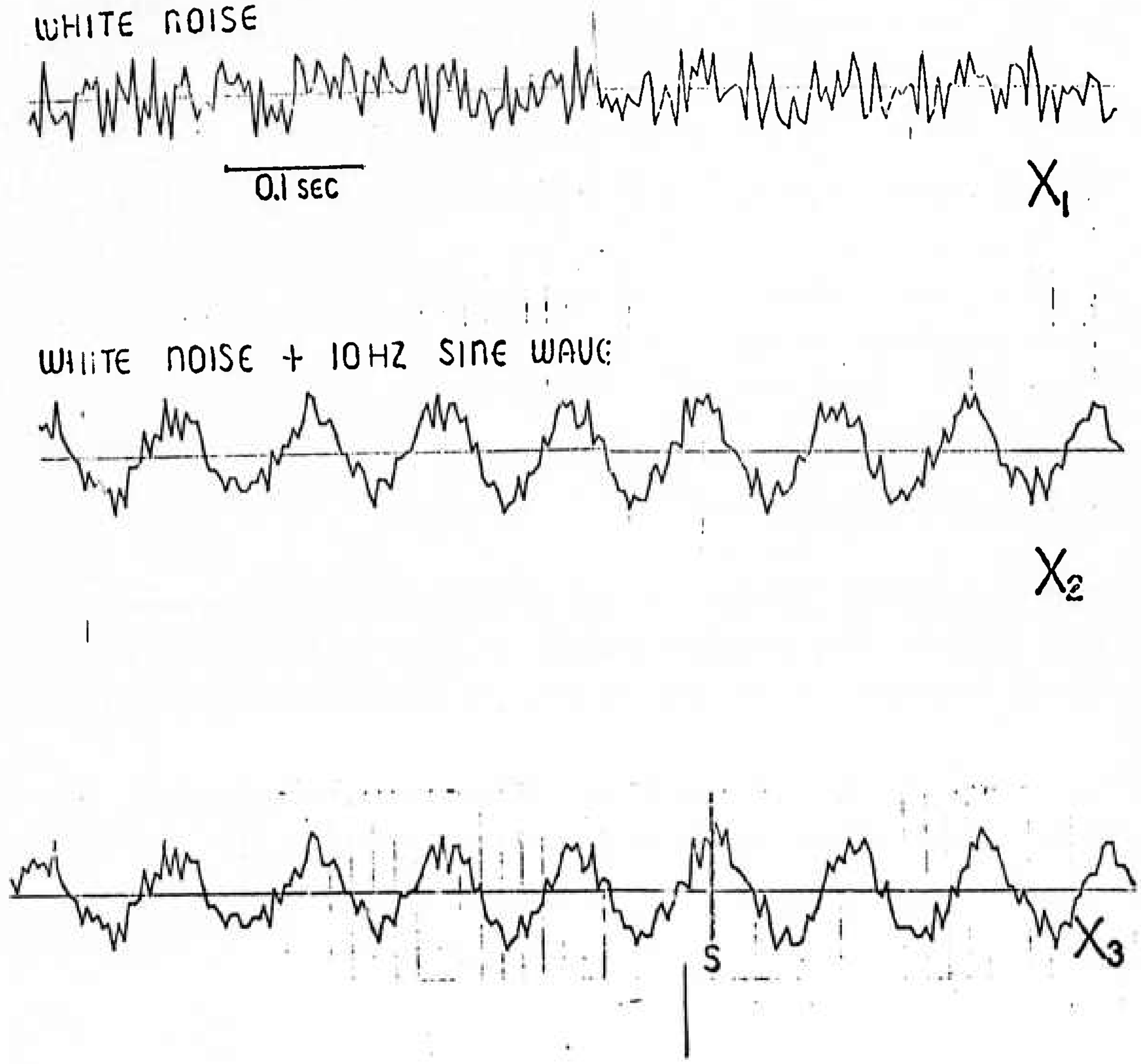
The following tests were performed:

ORTHO was Run on	Data Set (order of channels-left one is always a basis)
1. full length of epoch	(f = 4Hz, DS 1, x_1 x_2 x_3)
2. full length of epoch	(f = 4Hz, DS 2, x_1 x_2 x_3)
3. full length of epoch	(f =10Hz, DS 3, x_1 x_2 x_3)
4. full length of epoch	(f = 4Hz, DS 1, x_3 x_2 x_1)
5. 70 samples before VER	(f = 4Hz, DS 1, x_1 x_2 x_3)
6. 70 samples before VER	(f =10Hz, DS 3, x_1 x_2 x_3)
7. 130 samples before VER	(f = 4Hz, DS 1, x_1 x_2 x_3)
8. 130 samples before VER	(f =10Hz, DS 3, x_1 x_2 x_3)

Preliminary Conclusions

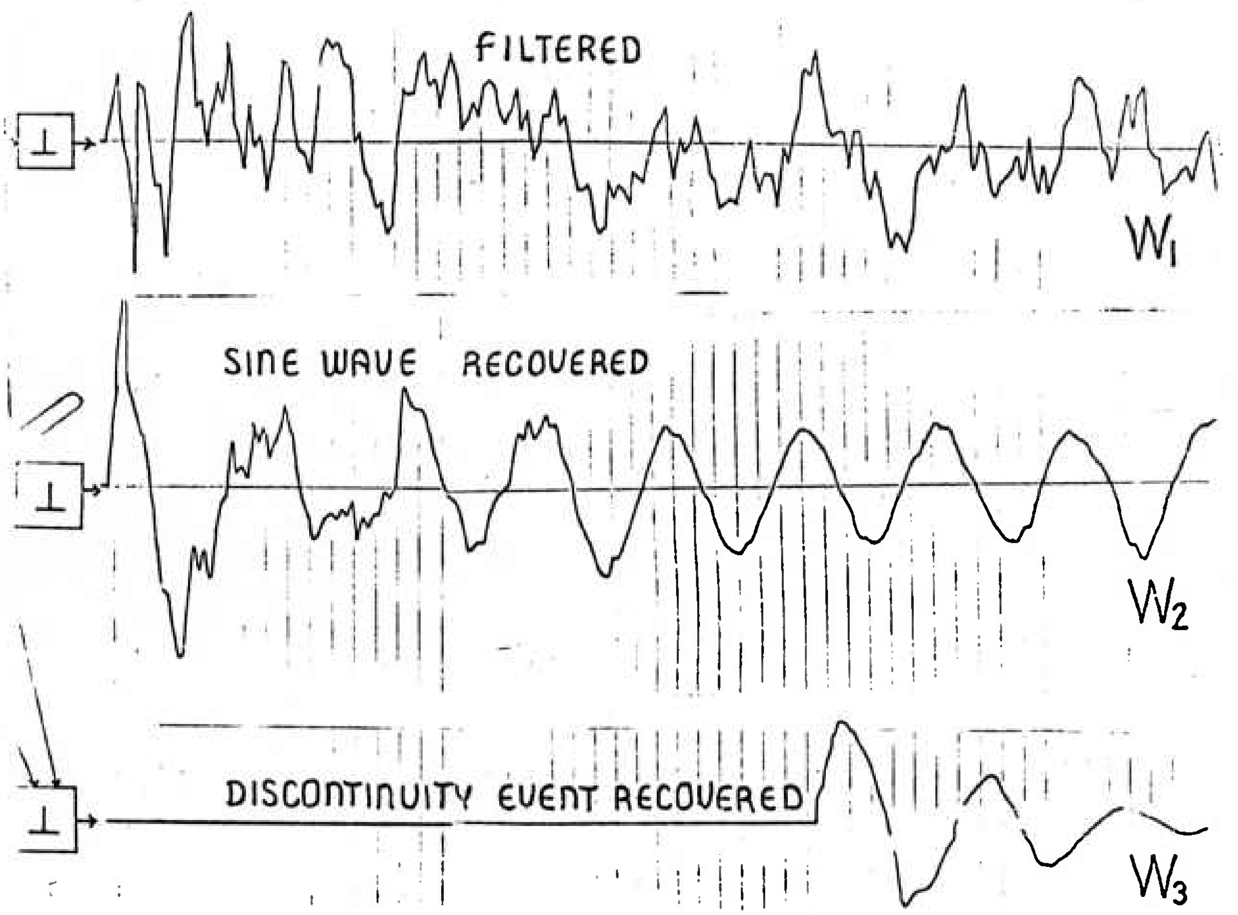
ORTHO separated VER very well on all data sets, only one difference being that when full length of epoch was used the amplitude of separated VER was about twice as large as if only 130 or 70 samples were used.

Thus is appears that with the present filter constants only about 100 samples before VER are needed to get good separation of VER.



SYNTHETIC DATA FOR ORTHOGONAL DERIVATION

FIG. 29



FILTERING EFFECT OF ORTHOGONAL DERIVATION

FIG. 30

STEPWISE DISCRIMINANT ANALYSIS RUN

SUMMARIES

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: CH4RAW

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 4-Eye (Inferior Orbital) Ears

SUBJECT'S INITIAL: XXX

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

48/Red, 48/Green, 47/Blue

F-LEVEL FOR INCLUSION: 0.0

F-LEVEL FOR DELETION: 0.0

NO. OF STEPS RUN: 82

MEMO:

The following results are after 10 steps.

RESULTS OF RUN: A-1

VARIABLES SELECTED: (in order)

20, 44, 13, 9, 32, 26, 29, 4, 12, 48

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
88 .81 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.54687	0.11940
Approx.- F	58.00134	24.81071

FINAL CLASSIFICATION MATRIX:

	R	G	B
R	45	1	2
G	1	41	6
B	1	5	41

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: CH3NEW

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 3-Occipital/Ears

SUBJECT'S INITIAL: XXX

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

24/Red, 24/Green, 24/Blue,
-24/New Red, -24/New Green, -23/New Blue

F-LEVEL FOR INCLUSION: 0.01

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO:

RESULTS OF RUN: A-2

VARIABLES SELECTED: (in order)

32, 41, 31, 47, 17, 12, 44, 19, 22, 25

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
100.00 o/o	85.92 o/o

	INITIAL	FINAL
U-STAT	0.51348	0.04684
Approx.- F	32.68846	21.72443

FINAL CLASSIFICATION MATRIX:

	R	G	B
R	24	0	0
G	0	24	0
B	0	0	24
New Red	18	0	6
New Green	0	24	0
New Blue	4	0	19

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: CH3RAW

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE 4 MSEC.

CHANNEL PROCESSED: 3 - Occipital/Ears

SUBJECT'S INITIAL: XXX

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

48/Red, 48/Green, 47/Blue

F-LEVEL FOR INCLUSION: 0.0

F-LEVEL FOR DELETION: 0.0

NO. OF STEPS RUN: 10

MEMO:

RESULTS OF RUN: A-3

VARIABLES SELECTED: (in order)

41, 34, 45, 29, 26, 22, 33, 10, 68, 65

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
92 . 31o/o	. o/o

	INITIAL	FINAL
U-STAT	0.53200	0.06551
Approx.- F	61.57886	38.08063

FINAL CLASSIFICATION MATRIX:

	R	G	B
R	44	0	4
G	0	48	0
B	7	0	40

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: BCI07M

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 3-Occipital/Ears

SUBJECT'S INITIAL: XXX

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

48/Red, 48/Green, 47/Blue

F-LEVEL FOR INCLUSION: 0.0

F-LEVEL FOR DELETION: 0.0

NO. OF STEPS RUN: 25

MEMO:

The results are after 25 steps.

RESULTS OF RUN: A-4

VARIABLES SELECTED: (in order)

41, 34, 45, 29, 26, 22, 33, 10, 68, 65,
36, 71, 79, 24, 21, 17, 20, 25, 27, 16,
70, 73, 39, 38, 80

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
100.00 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.53200	0.02622
Approx.- F	61.57886	24.01642

FINAL CLASSIFICATION MATRIX:

	R	G	B
R	48	0	0
G	0	48	0
B	0	0	47

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: C3GRBL

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE 1MSEC.

CHANNEL PROCESSED: 3-Occipital/Ears

SUBJECT'S INITIAL: XXX

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

48/Green, 47/Blue

F-LEVEL FOR INCLUSION: 0.0

F-LEVEL FOR DELETION: 0.0

NO. OF STEPS RUN: 10

MEMO:

RESULTS OF RUN: A-7

VARIABLES SELECTED: (in order)

41, 34, 45, 10, 37, 64, 73, 80, 59, 18

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
100 · 00 o/o	. o/o

INITIAL	FINAL
U-STAT 0-40792 Approx. - F 134.9834[illegible]	

FINAL CLASSIFICATION MATRIX:

	G	B
G	48	0
B	0	47

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: C3 REGR

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 3-Occipital/Ears

SUBJECT'S INITIAL: XXX

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

48/Red, 48/Green

F-LEVEL FOR INCLUSION: 0.0

F-LEVEL FOR DELETION: 0.0

NO. OF STEPS RUN: 10

MEMO:

RESULTS OF RUN: A-8

VARIABLES SELECTED: (in order)

33, 40, 10, 46, 29, 41, 21, 73, 64, 36

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
100.00 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.57485	0.11682
Approx.- F	69.51984	64.25989

FINAL CLASSIFICATION MATRIX:

	R	G
R	48	0
G	0	48

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: CH3RED

DATA CODE·

NO. OF TIME POINTS: 80

SAMPLING RATE - 1 MSEC.

CHANNEL PROCESSED: 30-Occipital/Ears

SUBJECT'S INITIAL: XXX

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

48/Red, 95/Nonred

F-LEVEL FOR INCLUSION: 0.0

F-LEVEL FOR DELETION: 0.0

NO. OF STEPS RUN:

MEMO: Here Group 'nonred' consists of 48/Green and 47/Blue

RESULTS OF RUN: A-9

VARIABLES SELECTED: (in order)

34, 29, 33, 26, 69, 38, 55, 51, 47, 36

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
93·71 o/o	. o/o

INITIAL	FINAL
U-STAT 082891	0.34836
Approx.- F29.10364	24.69171

FINAL CLASSIFICATION MATRIX:

	R	Nonred
R	45	3
Nonred	6	89

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: CH3GRN

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 3-Occipital/Ears

SUBJECT'S INITIAL: XXX

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

48/Green, 95/nongreen

F-LEVEL FOR INCLUSION: 0.0

F-LEVEL FOR DELETION: 0.0

NO. OF STEPS RUN: 10

MEMO:

Here group 'Nongreen' consists of 48/Red and 47/Blue

RESULTS OF RUN: A-10

VARIABLES SELECTED: (in order)

41, 34, 45, 10, 73, 64, 37, 20, 33, 28

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
100 '00 o/o	. o/o

	INITIAL	FINAL
U-STAT	0 58025	0.13568
Approx.- F	101.99918	84.08607

FINAL CLASSIFICATION MATRIX:

	G	Nongreen
G	48	0
Nongreen	0	95

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: CH3BLU

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 3-Occipital/Ears

SUBJECT'S INITIAL: XXX

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

47/Blue, 96/Nonblue

F-LEVEL FOR INCLUSION: 1.0

F-LEVEL FOR DELETION: 0.5

NO. OF STEPS RUN: 43

MEMO:

1. Here the group 'Nonblue' consists of 48/Red and 48/Green
2. The following results are after 10 steps.

RESULTS OF RUN: A-11

VARIABLES SELECTED: (in order)

40, 30, 26, 67, 33, 22, 38, 24, 21,

Note: On step 10, variable 26 was removed as it had a F-value of 0.2100

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
95 . 11 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.72677	0.35493
Approx.- F	53.00856	30.44206

FINAL CLASSIFICATION MATRIX:

	B	Nonblue
B	42	5
Nonblue	2	94

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: C3REBL

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 3-Occipital/Ears

SUBJECT'S INITIAL: XXX

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

48/Red, 47/Blue

F-LEVEL FOR INCLUSION: 0.0

F-LEVEL FOR DELETION: 0.0

NO. OF STEPS RUN: 10

MEMO:

RESULTS OF RUN: A-12a

VARIABLES SELECTED: (in order)

29, 33, 26, 22, 79, 24, 21, 17, 20, 16

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
97 . 90 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.81549	0.19387
Approx.- F	21-04158	32.92717

FINAL CLASSIFICATION MATRIX:

	R	B
R	48	0
B	2	45

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: CH2RAW

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 2-Vertex/Ears

SUBJECT'S INITIAL: XXX

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

48 Red, 48/Green, 47/Blue

F-LEVEL FOR INCLUSION: 0.0

F-LEVEL FOR DELETION: 0.0

NO. OF STEPS RUN: 81

MEMO:

The following results are after 15 steps

RESULTS OF RUN: A-14

VARIABLES SELECTED: (in order)

50, 40, 69, 61, 36, 30, 44, 74, 65, 80, 42, 38, 56, 32, 27

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
. o/o	. o/o

	INITIAL	FINAL
U-STAT	0.63463	0.19242
Approx.- F	40.29965	10.74932

FINAL CLASSIFICATION MATRIX:

	R	G	B
R	44	2	2
G	1	41	6
B	2	4	41

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: CH2RAW

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE -4 MSEC.

CHANNEL PROCESSED: 2-Verten/Ears

SUBJECT'S INITIAL: XXX

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

48/Red, 48, Green, 47/Blue

F-LEVEL FOR INCLUSION: 0.0

F-LEVEL FOR DELETION: 0.0

NO. OF STEPS RUN: 10

MEMO:

RESULTS OF RUN: A-15

VARIABLES SELECTED: (in order)

50, 40, 69, 61, 36, 30, 44, 74, 65, 80

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
83 · 92 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.63463	0.24954
Approx.- F	40.29965	13.12502

FINAL CLASSIFICATION MATRIX:

	R	G	B
R	41	3	4
G	3	41	4
B	4	7	36

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: CH1RAW

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 1-Frontal/Ears

SUBJECT'S INITIAL: XXX

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

48/Red, 48/Green, 47/Blue

F-LEVEL FOR INCLUSION: 0.0

F-LEVEL FOR DELETION: 0.0

NO. OF STEPS RUN: 10

MEMO:

RESULTS OF RUN: A-18

VARIABLES SELECTED: (in order)

50, 69, 61, 41, 32, 30, 20, 36, 4, 40

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
. o/o	. o/o

	INITIAL	FINAL
U-STAT	0.77242	0.28146
Approx.- F	20.62447	11.59229

FINAL CLASSIFICATION MATRIX:

	R	G	B
R	35	4	9
G	4	42	2
B	8	3	36

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: TESTRN

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: CHI-Top Occipital/Ears, CHZ-Central Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

32/1, 32/5, 32/A,
-32/U, -32/F, -32/T

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN:

MEMO:

1. Only the first 10 variables, i.e. first 40 MSU were considered in this analysis.
2. The odd variables were taken from CHl, and the even variables were taken from CH2.

RESULTS OF RUN: B-1

VARIABLES SELECTED: (in order)

Channel 1

6, 1, 3, 8, 7, 9, 4, 2, 10, 5

Channel 2

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
47 · 92 o/o	34·38 o/o

	INITIAL	FINAL
U-STAT	0.96796	0.84322
Approx. - F	1.53907	0.74766

FINAL CLASSIFICATION MATRIX:

	1	5	A
1	15	8	9
5	9	15	8
A	11	5	16
U	10	11	11
F	10	10	12
T	11	8	13

1=Violet
5=Green-Yellow
A=Red
U=Violet
5=Green-Yellow
T=Red

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: TESTRN

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 4-Left Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

64/1, 64/2, 64/3, 64/4, 64/5,
64/6, 64/7, 64/8, 64/9, 64/A

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO:

The first 10 variables, ie. first 40 MSEC and last 14 variables ie. last 56 MSEC of the epoch were not considered in this analysis.

RESULTS OF RUN: B-3

VARIABLES SELECTED: (in order)

54, 44, 62, 38, 19, 35, 51, 32, 28, 23

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
35.90 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.87613	0.38892
Approx.- F	9.89643	7.00876

FINAL CLASSIFICATION MATRIX:

1	40	2	1	5	3	3	3	3	0	4
2	6	11	12	6	2	2	5	8	2	10
3	7	12	24	7	1	0	3	4	2	4
4	8	1	7	26	6	4	3	3	2	4
5	6	6	6	11	13	1	5	6	6	4
6	4	3	6	9	5	8	3	13	9	4
7	8	2	7	9	2	1	17	8	3	7
8	6	7	8	1	7	1	6	20	7	1
9	4	0	2	1	0	1	7	7	33	9
A	3	3	3	2	0	1	1	1	12	38

35.9 o/o

1=410nm
2=465nm
3=490nm
4=515nm
5=530nm
6=550nm
7=575nm
8=595nm
9=620nm
A=660nm

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: TESTRN

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 2- Central Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

64/1, 64/2, 64/3, 64/4, 64/5,
64/6, 64/7, 64/8, 64/9, 64/A

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO:

The first 10 variables, i.e. first 40 MSCE and last 14 variables i.e. last 56 MSOE of the epoch were not considered in this analysis.

RESULTS OF RUN: B-4

VARIABLES SELECTED: (in order)

55, 35, 63, 38, 27, 24, 33, 43, 52, 21

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
50.10 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.67121	0.11323
Approx. - F	34.28992	17.76807

FINAL CLASSIFICATION MATRIX:

1	45	0	2	4	2	4	3	0	1	3
2	6	34	13	2	3	1	0	4	1	3
3	4	16	33	6	1	2	0	1	0	1
4	5	4	7	23	10	4	5	2	2	2
5	2	3	4	5	27	12	4	4	1	2
6	1	6	8	10	15	8	6	3	5	2
7	4	5	0	7	0	3	32	8	3	2
8	1	7	4	0	4	3	2	31	10	2
9	0	1	0	2	0	0	1	7	41	12
A	4	2	0	0	1	2	0	3	5	47

50.10 o/o

1=410nm
2=465nm
3=490nm
4=515nm
5=530nm
6=550nm
7=575nm
8=595nm
9=620nm
A=660nm

Key		
R	=	Red
G	=	Green
B	=	Blue
Y	=	Yellow
W	=	White
P	=	Purple
BG	=	Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: TESTRN

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 1-Top Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

64/1, 64/2, 64/3, 64/4, 64/5, 64/6,
64/7, 64/8, 64/9, 64/A

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO:

RESULTS OF RUN: B-5

VARIABLES SELECT[illegible] (in order)

53, 29, 63, 32, 42, 25, 28, 23, 21, 48

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
50.78 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.70841	0.19956
Approx.- F	28.81210	14.08724

FINAL CLASSIFICATION MATRIX:

	1	2	3	4	5	6	7	8	9	A
1	44	1	1	1	0	4	2	0	7	4
2	3	27	16	9	1	2	1	2	3	0
3	4	16	26	9	1	2	0	2	4	0
4	3	10	2	35	5	5	1	2	1	0
5	1	4	0	9	34	1	8	5	2	0
6	1	3	6	8	7	17	9	4	6	3
7	6	4	1	3	9	9	28	1	3	0
8	1	7	1	12	6	5	5	16	5	6
9	7	4	1	3	3	5	0	2	29	10
A	4	1	3	0	0	1	0	1	5	49

50.78 o/o

1=410nm
2=465nm
3=490nm
4=515nm
5=530nm
6=550nm
7=575nm
8=595nm
9=620nm
A=660nm

Key		
R	=	Red
G	=	Green
B	=	Blue
Y	=	Yellow
W	=	White
P	=	Purple
BG	=	Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: TESTRN

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 3-Bottom Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

64/1, 64/2, 64/3, 64/4, 64/5,
64/6, 64/7, 64/8, 64/9, 64/A

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO:

The first 10 variables, ie. first 40 MSEC and last 14 variables ie. last 56 MSEC of the epoch were not considered in this analysis.

RESULTS OF RUN: B-6

VARIABLES SELECTED: (in order)

35, 54, 44, 32, 59, 36, 66, 55, 20, 46

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
31·70 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.87796	0.44194
Approx. - F	9.72992	6.00219

FINAL CLASSIFICATION MATRIX:

	1	2	3	4	5	6	7	8	9	A
1	46	1	2	1	0	2	2	6	1	3
2	7	20	9	2	3	5	8	4	1	3
3	7	10	24	2	6	6	3	4	1	3
4	6	10	11	4	13	6	2	7	1	4
5	4	5	10	4	16	6	7	3	6	3
6	5	2	5	5	6	13	9	3	7	9
7	5	5	4	2	9	5	20	4	5	5
8	14	5	4	0	6	5	4	5	16	5
9	5	3	1	0	3	2	7	3	26	14
A	5	4	0	0	3	3	5	5	10	29

31.70°/o

1=410nm
2=465nm
3=490nm
4=515nm
5=530nm
6=550nm
7=575nm
8=595nm
9=620nm
A=660nm

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: TESTRN

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 5-Right Occipital /Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

64/1, 64/2, 64/3, 64/4, 64/5,
64/6, 64/7, 64/8, 64/9, 64/A

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO:

The first 10 variables, ie. first 40MSEC and last 14 variables ie. last 56 MSEC of the epoch were not considered in this analysis.

RESULTS OF RUN: B-7

VARIABLES SELECTED: (in order)

64, 55, 33, 25, 19, 44, 66, 60, 54, 27

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
34.00 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.84798	0.42593
Approx.- F	12.54898	6.29086

FINAL CLASSIFICATION MATRIX:

	1	2	3	4	5	6	7	8	9	A
1	39	1	1	4	0	0	2	5	4	8
2	10	18	9	6	4	5	3	7	1	1
3	7	9	11	11	7	6	2	6	4	1
4	9	5	6	22	8	3	1	2	3	5
5	1	2	4	10	31	5	3	3	3	2
6	5	6	5	6	8	12	5	6	4	7
7	2	0	2	3	13	7	11	7	10	9
8	6	10	3	5	4	5	8	10	11	2
9	5	3	1	2	3	2	2	5	31	10
A	10	2	1	3	0	3	2	2	8	33

34.00 o/o

1=410nm
2=465nm
3=490nm
4=515nm
5=530nm
6=550nm
7=575nm
8=595nm
9=620nm
A=660nm

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: CLUSTR

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 1

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

32/Red, 32/Green, 32/Blue,
-32/1, -32/3, -32/5, -32/6, -32/7, -32/8, -32/9

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO: The first 10 variables, ie. first 40 MSEC and last 14 variables ie. last 56 MSEC of the epoch were not considered in this analysis.

RESULTS OF RUN: B-8

VARIABLES SELECTED: (in order)

53, 44, 62, 29, 67, 48, 38, 42, 74, 51

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
91.67 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.41869	0.08384
Approx. - F	64.56099	20.60997

FINAL CLASSIFICATION MATRIX:

	R	G	B
R	31	0	1
G	0	28	4
B	0	3	29
1	1	8	23
3	1	23	8
5	0	14	18
6	2	11	19
7	3	10	19
9	15	1	16

1=410nm
2=465nm
3=490nm
4=515nm
5=530nm
6=550nm
7=575nm
8=595nm
9=620nm
A=660nm

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: CLUSTR DATA CODE:

NO. OF TIME POINTS: 80 SAMPLING RATE = MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

32/Red, 32/Green, 32/Blue,
-32/1, -32/3, -32/5, -32/6, -32/7, -32/8, -32/9

F-LEVEL FOR INCLUSION: 0.010 F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO: The first 10 variables, ie. first 40 MSEC and last 14 variables ie. last 56 MSEC of the epoch were not considered in the analysis.

RESULTS OF RUN: B-9

VARIABLES SELECTED: (in order)

52, 73, 54, 35, 38, 63, 42, 25, 32, 26

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
89 · 58 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.53898	0.09510
Approx.- F	39.77399	18.83817

FINAL CLASSIFICATION MATRIX:

	R	G	B
R	30	1	1
G	0	27	5
B	1	2	29
1	5	10	17
3	1	6	25
5	3	14	15
6	10	14	8
7	5	15	12
8	9	6	17
9	14	3	15

1=410nm
2=465nm
3=490nm
4=515nm
5=530nm
6=550nm
7=575nm
8=595nm
9=620nm
A=660nm

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: TESTRN

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 1-Top Occipital/Ears; 2-Central Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

32/1, 32/5, 32/A
-32/4, -32/F, -32/T

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO:

1. Variables 1-10 ie. first 40 MSEC and variables 67-80 ie. last 56MSEC were not considered in thisf analysis.
2. Channels 1 and 2 were simultaneously analyzed by choosing the odd variables from CH1 and even from CH2.

RESULTS OF RUN: C-1

VARIABLES SELECTED: (in order)

Channel 2 Variables

38, 63, 30, 28, 44, 49, 21, 46, 23

Channel 1 Variables

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
93·75 o/o	84·88 o/o

	INITIAL	FINAL
U-STAT	0.59704	0.08669
Approx.- F	31.38367	20.12962

FINAL CLASSIFICATION MATRIX:

	1	5	A
1	31	0	1
5	3	29	0
A	0	2	30
U	24	3	5
F	6	26	0
T	0	1	31

1=Violet
5=Green-Yellow
A=Red
U=Violet
F=Green-Yellow
T=Red

Key		
R	=	Red
G	=	Green
B	=	Blue
Y	=	Yellow
W	=	White
P	=	Purple
BG	=	Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: TESTRN

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 1-Top Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

32/1, 32/5, 32/A,
-32/4, -32/F, -32/T

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO:

Variables 1-10 ie. first 40 MSEC and variables 67-80 ie. last 56 MSEC were not considered in this analysis.

RESULTS OF RUN: C-2

VARIABLES SELECTED: (in order)

63, 31, 52, 45, 48, 24, 21, 28, 66, 55

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
. o/o	. o/o

	INITIAL	FINAL
U-STAT	0.59479	0.09828
Approx.- F	31.67860	18.39432

FINAL CLASSIFICATION MATRIX:

	1	5	A
1	29	1	2
5	0	31	1
A	1	1	30
U	21	4	7
F	0	30	2
T	1	1	30

1=Violet
5=Green-Yellow
A=Red
U=Violet
F=Green-Yellow
T=Red

Key

R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: TESTRN

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 1-Top Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

32/1, 32/4, 32/5, 32/6, 32/A
-32/0, -32/C, -32/F, -32/S, -32/T

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO:

Variables 1-10 ie. first 40 MSEC and variables 67-80 ie. last 56 MSEC of epoch were not considered in this analysis.

RESULTS OF RUN: C-3

VARIABLES SELECTED: (in order)

63, 31, 55, 28, 42, 25, 21, 23, 37, 49

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
69.38 o/o	66.88 o/o

	INITIAL	FINAL
U-STAT	0.62170	0.12301
Approx.- F	23.57954	10.24572

FINAL CLASSIFICATION MATRIX:

	1	4	5	6	A
1	27	1	0	0	4
4	0	21	3	6	2
5	1	7	18	5	1
6	1	2	6	21	2
A	4	0	0	4	24
0	22	2	0	3	5
C	0	26	2	4	0
F	0	7	21	3	1
S	2	12	6	10	2
T	0	2	0	2	28

1=Violet
4=Green
5=Grn.-Yellow
6=Yellow-Grn.
A=Red
0=Violet
C=Green
F=Grn.-Yellow
S=Yellow-Grn.
T=Red

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: TESTRN

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

32/1, 32/4, 32/5, 32/6, 32/A
-32/0, -32/C, -32/F, -32/S, -32/T

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO:

1. Variables 1-10 ie. first 40 MSEC and variables 67-80 ie. last 56 MSEC of the epoch were not considered in this analysis.
2. This run was made along with another similar run where the data used was preprocessed through a digital filter.

RESULTS OF RUN: C-4

VARIABLES SELECTED: (in order)

37, 54, 64, 42, 28, 24, 30, 49, 46, 33

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
66.25 o/o	57.50 o/o

	INITIAL	FINAL
U-STAT	0.64535	0.13095
Approx.- F	21.29509	9.85034

FINAL CLASSIFICATION MATRIX:

	1	4	5	6	A
1	29	1	0	1	1
4	3	19	5	3	2
5	4	4	15	9	0
6	1	5	7	15	4
A	1	0	0	3	28
0	23	2	1	3	3
C	1	19	7	2	3
F	1	8	19	4	0
S	7	8	6	8	3
T	1	0	1	1	23

1=Violet
4=Green
5=Grn.-Yellow
6=Yellow-Grn.
A=Red
0=Violet
C=Green
F=Grn.-Yellow
S=Yellow-Grn.
T=Red

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: TESTRN DATA CODE:

NO. OF TIME POINTS: 80 SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

32/1, 32/4, 32/5, 32/G, 32/A,
-32/U, -32/C, -32/F, -32/S, -32/T

F-LEVEL FOR INCLUSION: 0.010 F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN. 10

MEMO:

1. Variables 1-10 ie. first 40 MSEC and variables 67-80 ie. last 56 MSEC were not considered.
2. The data was preprocessed through a low-pass digital filter with time varying time constants, which also removed "DC" by "zero-meaning" it.
3. The plot of first-2-canonical variables was stratified on the third one.

RESULTS OF RUN: C-5

VARIABLES SELECTED: (in order)

55, 66, 38, 45, 28, 25, 33, 24, 22, 49

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
70.00 o/o	63.75 o/o

	INITIAL	FINAL
U-STAT	0.52857	0.07873
Approx.- F	34.56050	13.25951

FINAL CLASSIFICATION MATRIX:

	1	4	5	6	A
1	30	1	0	0	1
4	3	23	4	2	0
5	1	8	17	6	0
6	1	5	10	13	3
A	2	0	0	1	29
0	23	3	0	3	3
C	1	22	6	2	1
F	0	4	19	9	0
S	3	10	10	7	2
T	1	0	0	0	31

1=Violet
4=Green
5=Grn.-Yellow
6=Yellow-Grn
A=Red
0=Violet
C=Green
F=Grn-Yellow
S=Yellow-Grn
T=Red

Key

R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: C1D124 DATA CODE:

NO. OF TIME POINTS: 80 SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 1-Top Occipital/Ears SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

30/Red, 30/Green, 30/Blue

F-LEVEL FOR INCLUSION: 0.010 F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 15

MEMO:

The results are reported after 10 steps.

RESULTS OF RUN: C-6

VARIABLES SELECTED: (in order)

74, 37, 39, 52, 18, 72, 41, 12, 68, 80

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
91 . 11 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.66125	0.14972
Approx. - F	22.28453	12.35823

FINAL CLASSIFICATION MATRIX:

	R	G	B
R	27	3	0
G	2	27	1
B	0	2	28

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: GRNRAW

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 1-Top Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

10/Red, 10/Green, 10/Blue, -30/WARGRN

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO:

Red, Green, Blue are 10 averages each computed from sets of 6 epochs per average.

RESULTS OF RUN: C-7

VARIABLES SELECTED: (in order)

39, 37, 58, 75, 48, 57, 13, 12, 1, 28

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
100.00 o/o	43.33 o/o

	INITIAL	FINAL
U-STAT	0.22331	0.00076
Approx.- F	46.95537	63.60176

FINAL CLASSIFICATION MATRIX:

	RA	GA	BA
RA	10	0	0
GA	0	10	0
BA	0	0	10
WARGRN	12	13	5

RA=Red Average
GA=Green Aver.
BA=Blue Aver.
WARGRN=Raw Green

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: AVERAG

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 1-Top Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

10/Red, 10 Green, 10/Blue,
-5/Avergrn

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO:
Red= are 10 averages of 6 epochs each
Green= are 10 averages of 6 epochs each
Blue= are 10 averages of 6 epochs each
AVEGRN= are 5 averages of 6 epochs each

RESULTS OF RUN: C-7a

VARIABLES SELECTED: (in order)

39, 37, 58, 75, 48, 57, 13, 12, 1, 28

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
100.00 o/o	40.00 o/o

	INITIAL	FINAL
U-STAT	0.22331	0.00076
Approx.- F	46.9553?	63.60176

FINAL CLASSIFICATION MATRIX:

	RED	GREEN	BLUE
RED	10	0	0
GREEN	0	10	0
BLUE	0	0	10
AVEGRN	2	2	1

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: RAWRGB

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 1-Top Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

30/Red, 30/Green, 30/Blue,
-30/REDRAW, -30/GRNRAW, -30/BLURAW

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO:

The first 10 variables ie. the first 40 MSEC of the epoch were not considered in this analysis

RESULTS OF RUN: C-8

VARIABLES SELECTED: (in order)

74, 37, 39, 54, 72, 68, 35, 41, 19, 63

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
90 .00 o/o	63 . 33 o/o

	INITIAL	FINAL
U-STAT	0.60871	0.11303
Approx. - F	27.96211	15.4009

FINAL CLASSIFICATION MATRIX:

	R	G	B
R	29	1	0
G	4	26	0
B	3	1	26
R2	24	4	2
G2	5	21	4
B2	9	9	12

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: AVERGB

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 1-Top Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

10/REDAVE, 10/GRNAVE, 10/BLUAVE,
-30/Red, -30/Green, -30/Blue

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO:

REDAVE = are 10 averages of 6 epoch each
GRNAVE= are 10 averages of 6 epoch each
BLUAVE = are 10 averages of 6 epoch each

RESULTS OF RUN: C-9

VARIABLES SELECTED: (in order)

39, 37, 58, 75, 48, 57, 13, 12, 1, 28

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
100.00 o/o	70.00 o/o

	INITIAL	FINAL
U-STAT	0.22331	0.00076
Approx. - F	46.95537	63.60176

FINAL CLASSIFICATION MATRIX:

	R AVE	G AVE	B AVE
RAVE	10	0	0
GAVE	0	10	0
BAVE	0	0	10
RED	22	7	1
GREEN	8	15	7
BLUE	2	2	26

Key

R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: PAIRRB

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 1-Top Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

10/REDAVE, 10/BLUAVE,
-10/GRNAVE, -30/GRNRAW, -30/REDRAW, -30/BLURAW

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO:

1. REDAVE = are 10 averages of 6 epochs each
   BLUAVE = are 10 averages of 6 epochs each
   GRNAVE = are 10 averages of 6 epochs each
2. Predictive power of DF is computed for RED and BLUE only.

RESULTS OF RUN: C-10

VARIABLES SELECTED: (in order)

75, 41, 52, 35, 15, 65, 47, 48, 36, 12

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
100.00 o/o	96.67 o/o

	INITIAL	FINAL
U-STAT	0.10192	0.00098
Approx.- F	158.60815	914.23120

FINAL CLASSIFICATION MATRIX:

	RAVE	BAVE
RAVE	10	0
BAVE	0	10
GAVE	8	2
G	19	11
R	27	3
B	5	25

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: PA1RGB

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 1-Top Occipital/Ears

SUBJECT'S INITIAL:

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

10/GRNAVE, 10/BLUAVE,
-10/REDAVE, -30/REDRAW, -30/GRNRAW, -30/BLURAW

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO:

1. GRNAVE= are 10 averages of 6 epochs each.
   BLUAVE= are 10 averages of 6 epochs each.
   REDAVE= are 10 averages of 6 epochs each.
2. Predictive power of DF is computed for GREEN and BLUE only.

RESULTS OF RUN: C-11

VARIABLES SELECTED: (in order)

37, 75, 66, 51, 40, 31, 32, 24, 30, 17

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
100·00 o/o	85·00 o/o

	INITIAL	FINAL
U-STAT	0.32701	0.00082
Approx. - F	37.04491	1095.89941

FINAL CLASSIFICATION MATRIX:

	GAVE	BAVE
GAVE	10	0
BAVE	0	10
RAVE	3	7
R	8	22
G	24	6
B	3	27

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: PA1RRG

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 1-Top Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

10/REDAVE, 10/GRNAVE,
-10/BLUAVE, -30/BLURAW, -30/REDRAW, -30/GRNRAW

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO:

1. REDAVE=are 10 averages of 6 epochs each
   GRNAVE=are 10 averages of 6 epochs each
   BLUAVE=are 10 averages of 6 epochs each
2. Predictive power of DF is computed for RED and GREEN only.

RESULTS OF RUN: C-11a

VARIABLES SELECTED: (in order)

39, 14, 58, 49, 9, 53, 23, 24, 54, 26, 35

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
100.00 o/o	76.67 o/o

	INITIAL	FINAL
U-STAT	0.22810	0.00062
Approx.- F	60.91145	1450.26392

FINAL CLASSIFICATION MATRIX:

	RAVE	GAVE
RAVE	10	0
GAVE	0	10
BLUAVE	1	9
B	12	18
R	23	7
G	7	23

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: C2SPEC DATA CODE:

NO. OF TIME POINTS: 80 SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

30/RED, 30/GREEN, 30/BLUE,
-30/DERRED, -30/NRGGRN, -30/ULBBLU

F-LEVEL FOR INCLUSION: 0.010 F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO:

DERRED, NRGGRN, ULBBLU are simple 30 raw epochs of RED, GREEN, BLUE each. Such l names were used to get unique letters on the canonical maps.

RESULTS OF RUN: C-12

VARIABLES SELECTED: (in order)

73, 57, 51, 9, 53, 33, 47, 58, 66, 67

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
80 · 00 o/o	50 · 00 o/o

	INITIAL	FINAL
U-STAT	0.63625	0.21431
Approx. - F	24.86957	9.04907

FINAL CLASSIFICATION MATRIX:

·	R	G	B
R	23	5	2
G	7	22	1
B	2	1	27
R	14	6	10
G	6	16	8
B	4	11	15

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: TESTRN

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears

SUBJECT'S INITIAL:

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

64/Yellow, 64/ DUMMY

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO:

1. The first 10 variables ie. first 40 MSEC and last 14 variables ie. last 56 MSEC of epoch were not considered in this analysis.
2. "DUMMY" consists of 64 epochs of a constant value of 1.0 each at time point.

RESULTS OF RUN: C-13

VARIABLES SELECTED: (in order)

25, 62, 16, 43, 60, 48, 34, 41, 37, 44

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
98 .44 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.38685	0.07460
Approx.- F	199.71169	145.13947

FINAL CLASSIFICATION MATRIX:

	Y	DUMMY
Y	62	2
DUMMY	0	64

Key
- R = Red
- G = Green
- B = Blue
- Y = Yellow
- W = White
- P = Purple
- BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: TESTRN

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

64/RED, 64/DUMMY

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO:

1. The first 10 variables ie. first 40 MSEC and the last 14 variables ie. last 56 MSEC were not considered in this analysis.
2. 'DUMMY' consists of 64 epochs of a constant value of 1.0 each at each time point.

RESULTS OF RUN: C-13a

VARIABLES SELECTED: (in order)

14, 20, 22, 28, 44, 25, 55, 63, 18, 15

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
100 . 00 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.28878	0.05820
Approx. - F	310.31982	189.34644

FINAL CLASSIFICATION MATRIX:

	R	DUMMY
R	64	0
DUMMY	0	64

Key
- R = Red
- G = Green
- B = Blue
- Y = Yellow
- W = White
- P = Purple
- BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: TESTRN

DATA CODE:

NO. OF TIME POINTS:	80	SAMPLING RATE = 4 MSEC.	
CHANNEL PROCESSED:	2-Central Occipital/Ears	SUBJECT'S INITIAL:	CP
NUMBER of Cases/Names of Groups Analyzed:	64/GRN, 64/Dummy	('-' indicates group is being tested)	
F-LEVEL FOR INCLUSION:	0.010	F-LEVEL FOR DELETION:	0.005
NO. OF STEPS RUN:	10		

MEMO:

1. The first 10 variables, i.e. first 40 msec and the last 14 variables, i.e. last 56 msec of the epoch were not considered in this analysis.
2. 'Dummy' consists of 64 epochs of a constant value of 1.0 at each time point

RESULTS OF RUN: C-14

VARIABLES SELECTED: (in order)

14, 17, 38, 34, 43, 50, 29, 31, 16, 64

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
100 · 00 o/o	· o/o

	INITIAL	FINAL
U-STAT	0.42088	0.09659
Approx. - F	173.37497	109.42719

FINAL CLASSIFICATION MATRIX:

	G	Dummy
G	64	0
Dummy	0	64

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: TESTRN | DATA CODE:

NO. OF TIME POINTS: 80 | SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears | SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

64/BLUE, 64/Dummy

F-LEVEL FOR INCLUSION: 0.010 | F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO: 1. The first 10 variables, i.e. first 40 msec and the last 14 variables i.e. last 56 msec were not considered in this analysis.

2. 'Dummy' consists of 64 epochs of a constant value of 1.0 at each time point.

RESULTS OF RUN: C-16

VARIABLES SELECTED: (in order)

53, 16, 63, 21, 13, 26, 27, 58, 79, 69

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
99 • 22 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.39659	0.07121
Approx. - F	191.70583	152.59428

FINAL CLASSIFICATION MATRIX:

	B	Dummy
B	63	1
Dummy	0	64

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: TESTRN

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

64/ORANGE, 64/Dummy

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO: 1. The first 10 variables, i.e. first 40 msec and the last 14 variables, i.e. last 56 msec were not considered in this analysis.

2. 'Dummy' consists of 64 epochs of a constant value of 1.0 at each time point.

RESULTS OF RUN: C-18

VARIABLES SELECTED: (in order)

35, 59, 12, 42, 64, 32, 13, 61, 20, 14

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
98 · 44 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.43029	0.11126
Approx. F	166.82776	93.45956

FINAL CLASSIFICATION MATRIX:

	Ø	Dummy
Ø	62	2
Dummy	0	64

Key		
R	=	Red
G	=	Green
B	=	Blue
Y	=	Yellow
W	=	White
P	=	Purple
BG	=	Blue-Grn.
Ø	=	Orange

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: TESTRN

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

64/VIOLET, 64/Dummy

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO: 1. The first 10 variables, i.e. first 40 msec and the last 14 variables i.e. last 56 msec were not considered in this analysis.

2. 'Dummy' consists of 64 epochs of a constant value of 1.0 at each time point.

RESULTS OF RUN: C-19

VARIABLES SELECTED: (in order)

13, 35, 18, 46, 32, 11, 73, 14, 48, 65

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
96.88 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.46307	0.13690
Approx.- F	146.09857	73.76184

FINAL CLASSIFICATION MATRIX:

	V	Dummy
V	60	4
Dummy	0	64

Key

R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.
V = Violet

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: TESTRN

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

64/VIOLET, 64/Dummy

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO:
1. The variables 1-10 and 67-80 were ignored from this analysis
2. 'Dummy' consists of 64 epochs of a constant value of 1.0 at each time point.
3. The data for VIOLET was preprocessed through a digital filter with time varying time constants and also ability to 'zero mean'

RESULTS OF RUN: C-20

VARIABLES SELECTED: (in order)

30, 77, 26, 46, 35, 11, 37, 16, 66, 55

PERFORMANCE

Discriminability of Data	Predictive Power of DF
99.22 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.18704	0.06096
Approx. F	547.64795	180.22353

FINAL CLASSIFICATION MATRIX:

	V	Dummy
V	63	1
Dummy	0	64

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.
V = Violet

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: PGGRBL

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 1-Top Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

32/RED, 32/GREEN, 32/BLUE

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO: This is the 0th iteration of a series of 3 iterations where each iteration was run after rejecting outliers.

Outliers to be rejected: R9
G14, G18, G21, G29
B6, B14, B27

RESULTS OF RUN: D-1

VARIABLES SELECTED: (in order)

53, 44, 62, 29, 67, 48, 38, 42, 74, 51

PERFORMANCE	
Discriminability of Data	Predictive Power of D
91.67 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.41869	0.08384
Approx. - F	64.56099	20.60997

FINAL CLASSIFICATION MATRIX:

	R	G	B
R	31	0	1
G	0	28	4
B	0	3	29

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: STRIPD

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 1-Top Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

31/RED, 28/GREEN, 29/BLUE

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO: This is the first iteration after rejecting outliers identified by the 0th iteration.

Outliers to be rejected: R'8, R'29
G'17, G'28

RESULTS OF RUN: D-2

VARIABLES SELECTED: (in order)

53, 44, 74, 48, 67, 62, 38, 42, 51, 33

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
95.46 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.37660	0.03784
Approx. F	70.35324	31.47003

FINAL CLASSIFICATION MATRIX:

	R	G	B
R	29	0	2
G	0	26	2
B	0	0	29

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: CLUSTER

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 1-TopOccipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

29/RED, 26/GREEN, 29/BLUE

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO: This is the second iteration after rejecting outliers identified by the first iteration.

RESULTS OF RUN: D-3

VARIABLES SELECTED: (in order)

53, 44, 74, 48, 42, 38, 67, 51, 62, 33

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
100.00 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.35824	0.02612
Approx. F	72.55269	37.35187

FINAL CLASSIFICATION MATRIX:

	R	G	B
R	29	0	0
G	0	26	0
B	0	0	29

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: HAFRGB

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

32/RED, 32/GREEN, 32/BLUE, 32/YELLOW,
-50/1 RED, -50/2GREEN, -50/3BLUE, -50/4YELLOW

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 6

MEMO: RED, GREEN, BLUE, YELLOW are from 10 Color Experiment

1RED, 2GREEN, 3BLUE, 4YELLOW are from Opponent Color Experiment

RESULTS OF RUN: D-4

VARIABLES SELECTED: (in order)

52, 20, 76, 28, 63, 25

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
70 · 31 o/o	40 · 50 o/o

	INITIAL	FINAL
U-STAT	0.61527	0.16216
Approx. F	25.84549	16.90039

FINAL CLASSIFICATION MATRIX:

	R	G	B	Y
R	30	2	0	0
G	4	12	8	8
B	1	7	22	2
Y	0	3	3	26
1R	21	11	9	9
2G	11	13	22	4
3B	10	22	16	2
4Y	3	9	7	31

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: OPCRGB

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 2-Center Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

50/RED, 50/GREEN, 50/BLUE

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 6

MEMO:

RESULTS OF RUN: D-5

VARIABLES SELECTED: (in order)

53, 18, 25, 36, 33, 22

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
86 · 00 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.59632	0.21241
Approx. - F	49.75674	27.68384

FINAL CLASSIFICATION MATRIX:

	R	G	B
R	45	2	3
G	6	40	4
B	1	5	44

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: PURWHI

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

25/PUR001, 25/WHI001,
-25/PUR002,-25/WHI002

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 6

MEMO:

RESULTS OF RUN: D-6

VARIABLES SELECTED: (in order)

25, 75, 55, 24, 63, 72

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
98 · 00 o/o	86 · 00 o/o

	INITIAL	FINAL
U-STAT	0.44691	0.16066
Approx. - F	59.40335	37.44101

FINAL CLASSIFICATION MATRIX:

	P1	W1
P1	24	1
W1	0	25
P2	21	4
W2	3	22

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: YELWHI

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

25/YEL001, 25/WHI001,
-25/YEL002, -25/WHI002 .

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 6

MEMO:

RESULTS OF RUN: D-7

VARIABLES SELECTED: (in order)

63, 65, 72, 70, 56, 38

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
94 00 o/o	74 · 00 o/o

	INITIAL	FINAL
U-STAT	0.37577	0.21019
Approx. - F	79.73790	26.92953

FINAL CLASSIFICATION MATRIX:

	Y1	W1
Y1	22	3
W1	0	25
Y2	14	11
W2	2	23

Key		
R	=	Red
G	=	Green
B	=	Blue
Y	=	Yellow
W	=	White
P	=	Purple
BG	=	Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: BLUWHI DATA CODE:

NO. OF TIME POINTS: 80 SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

25/BLU001, 25/WHI001
-25/BLU002, -25/WHI002

F-LEVEL FOR INCLUSION: 0.010 F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 6

MEMO:

RESULTS OF RUN: D-8

VARIABLES SELECTED: (in order)

54, 64, 22, 61, 33, 75

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
100 · 00 o/o	92 · 00 o/o

	INITIAL	FINAL
U-STAT	0.39183	0.14790
Approx. F	74.50365	41.28970

FINAL CLASSIFICATION MATRIX:

	B1	W1
B1	25	0
W1	0	25
B2	24	1
W2	3	22

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: GRNWHI

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

25/GRN001, 25/WHI001,
-25/GRN002, -25/WHI002

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 6

MEMO:

RESULTS OF RUN: D-9

VARIABLES SELECTED: (in order)

66, 36, 57, 26, 68, 64

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
100.00 o/o	86.00 o/o

	INITIAL	FINAL
U-STAT	0.46778	0.17890
Approx. - F	54.61244	32.89241

FINAL CLASSIFICATION MATRIX:

	G1	W1
G1	25	0
W1	0	25
G2	21	4
W1	3	22

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: REDWHI

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

25/RED001, 25/WHI001,
-25/RED002, -25/WHI002

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 6

MEMO:

RESULTS OF RUN: D-10

VARIABLES SELECTED: (in order)

32, 9, 42, 49, 72, 68

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
100·00 o/o	90·00 o/o

	INITIAL	FINAL
U-STAT	0.39981	0.14562
Approx. - F	72.05644	42.04842

FINAL CLASSIFICATION MATRIX:

	R1	W1
R1	25	0
W1	0	25
R2	21	4
W2	1	24

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: REDBGR

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

25/RED001, 25/BGR001
-25/RED002, -25/BGR002

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 6

MEMO:

RESULTS OF RUN: D-11

VARIABLES SELECTED: (in order)

52, 38, 23, 79, 56, 36

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
100.00 o/o	88 .00 o/o

	INITIAL	FINAL
U-STAT	0.58376	0.18705
Approx. F	34.22533	31.14841

FINAL CLASSIFICATION MATRIX:

	R1	BG1
R1	25	0
BGI	0	25
R2	20	5
BG2	1	24

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: BLUYEL

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

25/BLU001, 25/YEL001,
-25/BLU002, -25/YEL002

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 6

MEMO:

RESULTS OF RUN: D-12

VARIABLES SELECTED: (in order)

33, 25, 38, 79, 24, 80

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
98 . 00o/o	86 . 00 o/o

	INITIAL	FINAL
U-STAT	0.46641	0.20416
Approx. F	54.91479	27.93663

FINAL CLASSIFICATION MATRIX:

	B1	Y1
B1	24	1
Y1	0	25
B2	19	6
Y2	1	24

Key

- R = Red
- G = Green
- B = Blue
- Y = Yellow
- W = White
- P = Purple
- BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: HIFLOW

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

50/RED, 50/GREEN, 50/BLUE,
-50/RED003, -50/GRN003, -50/BLU003,
-50/RED050, -50/GRN050, -50/BLU050

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 6

MEMO: A Discriminant Function was trained on higher intensity level data (attenuation 0.0) and applied on lower intensity level data (attenuation 0.30) and lower intensity level data (attenuation 0.50)

RESULTS OF RUN: D-13

VARIABLES SELECTED: (in order)

53, 18, 25, 36, 33, 22

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
86 · 00 o/o	42.33 o/o

INITIAL	FINAL
U-STAT 0.59632	0.21241
Approx. - F 49.75674	27.68384

FINAL CLASSIFICATION MATRIX:

	R	G	B	
R	45	2	3	
G	6	40	4	86%
B	1	5	44	
REDO.3	38	10	2	
GRNO.3	12	19	19	55%
BLUO.3	9	16	25	
REDO.5	27	23	0	
GRNO.5	24	9	17	30%
BLUO.5	15	26	0	

139

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: HIGL03

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

50/RED003, 50/GRN003, 50/BLU003,
-50/RED000, -50/GRN000, -50/BLU000,
-50/RED050 -50/GRN050, -50/BLU050

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 6

MEMO: A Discriminant Function was trained on intensity level data of attenuation 0.300 and applied on intensity level data of attenuation 0.000 and applied on intensity level data of attenuation 0.050.

RESULTS OF RUN: D-14

VARIABLES SELECTED: (in order)

27, 53, 66, 33, 70, 24

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
83·00 o/o	47· 00 o/o

INITIAL	FINAL
U-STAT 0.69650	0.24789
Approx. - F 32.02785	23.86777

FINAL CLASSIFICATION MATRIX:

	R0.3	G0.3	B0.3	
R0.3	46	4	0	
G0.3	7	37	6	
B0.3	4	4	42	
R0.0	18	17	15	
G0.0	9	19	12	46%
B0.0	3	16	31	
R0.5	25	16	9	
G0.5	15	20	15	49%
B0.5	8	14	28	

Key		
R	=	Red
G	=	Green
B	=	Blue
Y	=	Yellow
W	=	White
P	=	Purple
BG	=	Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: HIGL05

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE - 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

50/RED050, 50/GRN050, 50/BLU050,
-50/RED000, -50/GRN000, -50/BLU000,
-50/RED030, -50/GRN030, -50/BLU030

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 6

MEMO: A Discriminant Function was trained on intensity level data of attenuation 0.500 and applied on intensity level data of attenuation 0.000 and on intensity level data of attenuation 0.300

RESULTS OF RUN: D-15

VARIABLES SELECTED: (in order)

30, 66, 59, 22, 33, 36

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
56 . 67 o/o	41 . 00 o/o

	INITIAL	FINAL
U-STAT	0.70636	0.24912
Approx. - F	30.55482	23.75012

FINAL CLASSIFICATION MATRIX:

	R0.5	G0.5	B0.5	
R0.5	44	3	3	
G0.5	1	3	46	57%
B0.5	3	9	38	
R0.0	12	21	17	
G0.0	28	12	10	31%
B0.0	5	23	22	
R0.3	19	18	13	
G0.3	7	35	8	51%
B0.3	2	25	23	

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: COLNON

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

50/RED, 50/GREEN, 50/BLUE
-100/REDNON, -100/GRNNON, -100/BLUNON

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 6

MEMO:
'REDNON' = 50 PURPLE + 50 YELLOW
'GRNNON' = 50 BLU-GRN + 50 YELLOW
'BLUNON' = 50 BLU-GRN + 50 PURPLE

RESULTS OF RUN: D-17

VARIABLES SELECTED: (in order)

53, 13, 25, 36, 33, 22

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
86.00 o/o	33.67 o/o

	INITIAL	FINAL
U-STAT	0.59632	0.21241
Approx. F	49.75674	27.68384

FINAL CLASSIFICATION MATRIX:

	R	G	B
R	45	2	3
G	6	40	4
B	1	5	44
REDNON	28	25	47
GRNNON	24	10	66
BLUNON	12	25	63

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: APYHAF

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER of Cases/Names of Groups Analyzed: ('-' indicates group is being tested)

25/BGR, 25/ PURPLE, 25/YELLOW
-25/BGR002, -25/PUR002, -25/YEL002

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 6

MEMO:

RESULTS OF RUN: D-19

VARIABLES SELECTED: (in order)

25, 33, 66, 47, 26, 29

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
90·67 o/o	73·33 o/o

	INITIAL	FINAL
U-STAT	0.42022	0.09934
Approx. F	49.66949	24.26294

FINAL CLASSIFICATION MATRIX:

	BG	P	Y
BG	22	2	1
P	2	23	0
Y	2	0	23
BG2	17	3	5
P2	10	13	2
Y2	0	0	25

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: RGGRBI

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 1-Top Occipital/Ears

SUBJECT's INITIAL: CP

NUMBER/NAMES OF GROUPS ANALYZED:

32/RED, 32/GREEN, 32/BLUE

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 10

MEMO:

RESULTS OF RUN: D-20

VARIABLES SELECTED: (in order)

53, 44, 62, 29, 67, 48, 38, 42, 74, 51

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
91.. 67 o/o	. o/o

	INITIAL	FINAL
U-STAT	0.41869	0.08384
Approximate-F	64.56099	20.60997

FINAL CLASSIFICATION MATRIX:

	R	G	B
R	31	0	1
G	0	28	4
B	0	3	29

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: RGGRBL

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 1-Top Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER/NAMES OF GROUPS ANALYZED:

32/RED, 32/GREEN, 32/BLUE,
-32/A, -32/4, -32/2

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELE TION: 0.005

NO. OF STEPS RUN: 10

MEMO: The first 10 variables, i.e. the first 40 msec of the epoch are not considered in this analysis

RESULTS OF RUN: D-21

VARIABLES SELECTED: (in order)

75, 63, 53, 42, 21, 59, 55, 38, 35, 25

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
91 · 67 o/o	77 · 08 o/o

	INITIAL	FINAL
U-STAT	0.68915	0.12531
Approximate-F	32.42685	[illegible].32954

FINAL CLASSIFICATION MATRIX:

	R	G	B
R	31	0	1
G	1	27	4
B	0	2	30
A	26	1	5
4	0	28	4
2	1	11	20

Key

R	=	Red
G	=	Green
B	=	Blue
Y	=	Yellow
W	=	White
P	=	Purple
BG	=	Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: WINDOW DATA CODE:

NO. OF TIME POINTS: 80 SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears SUBJECT'S INITIAL: CP

NUMBER/NAMES OF GROUPS ANALYZED:

25/RED, -25/1RED, 25/GRN, -25/2GRN, 25/BLU, -25/3BLU

F-LEVEL FOR INCLUSION: 0.010 F-LEVEL FOR DELETION: 0.005

NO. OF STEPS RUN: 6

MEMO: Only the following windows were considered in this run:
(1) Variables 23-29, i.e. 92 msec-116msec,
(2) Variables 34-38, i.e. 136 msec-152 msec,
(3) Variables 43-48, i.e. 172 msec-192 msec,
(4) Variables 51-56, i.e. 204 msec-234 msec.

RESULTS OF RUN: D-23

VARIABLES SELECTED: (in order)

53, 23, 36, 48, 43, 25

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
78.67 o/o	64.00 o/o

	INITIAL	FINAL
U-STAT	0.56367	0.26751
Approximate-F	27.86734	10.42317

FINAL CLASSIFICATION MATRIX:

	R	G	B
R	21	2	2
G	1	19	5
B	1	5	19
1R	17	2	6
2G	2	13	10
3B	0	7	18

Key
R = Red
G = Green
B = Blue
Y = Yellow
W = White
P = Purple
BG = Blue-Grn.

BMD 07M STEPWISE DISCRIMINANT ANALYSIS

RUN CODE: GRNPUR

DATA CODE:

NO. OF TIME POINTS: 80

SAMPLING RATE = 4 MSEC.

CHANNEL PROCESSED: 2-Central Occipital/Ears

SUBJECT'S INITIAL: CP

NUMBER/NAMES OF GROUPS ANALYZED:

25/GRN001, 25/PUR001,
25/GRN002, -25/PUR002

F-LEVEL FOR INCLUSION: 0.010

F-LEVEL FOR DELE TION: 0.005

NO. OF STEPS RUN: 6

MEMO:

RESULTS OF RUN: D-22

VARIABLES SELECTED: (in order)

66, 36, 15, 25, 29, 19

PERFORMANCE	
Discriminability of Data	Predictive Power of DF
98 · 00 o/o	78 · 00 o/o

	INITIAL	FINAL
U-STAT	0.43226	0.19181
Approximate-F	63.04376	30.19640

FINAL CLASSIFICATION MATRIX:

	G1	P1
G1	24	1
P1	0	25
G2	24	1
P2	10	15

Key		
R	=	Red
G	=	Green
B	=	Blue
Y	=	Yellow
W	=	White
P	=	Purple
BG	=	Blue-Grn.

THE BCI FACILITY

Following is a brief description of the Brain Computer Interface Laboratory as implemented during the period. An addition of a 16K XDS 930, a random access drum, printer, two 7-track magnetic tape drives and a card reader to the BCI experiment loop was being made at the end of year 1974, and details on the new hardware and its role will appear in subsequent Reports.

OPERATIONAL SYSTEM DESCRIPTION

Three computers are involved in the Brain Computer Interface Project, the IMLAC PDS-1, the XDS 920 and the IBM 360/91. High speed parallel data links connect the three computers through a common interface box. The interface box allows the three computers to talk to each other by using a complex heirarchy of interrupt control.

The subject is placed in a sound proof room (see Figs 29 and 30). The room also shields the experiment from magnetic and electric fields including radio frequencies as well as allows reference to a single point to ground. The experimenter sits in the adjoining room in front of the control terminal. The EEG signals are preamplified and monitored and plotted using a standard EEG recording machine. The amplified signals are also sent to a 50 channel analog to digital converter which converts and feeds the signals to the XDS 920 computer. This XDS 920 acts as self driven data input controller and real time scheduler for the experiment. It also performs real time processing functions used in the creation of the EEG. These data sets contain complete information regarding the experiment.

The other two computers are the IBM 360/91 and the IMLAC PDS-1. The IBM 360/91 provides the main computing power for the experiments. Most of data reduction and data analysis is performed on the IBM 360/91 due

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to the availability of BMD statistical analysis software, its exceptionally large core memory and its excellent number crunching abilities.

The laboratory has a direct access post into the 360 through which one can read from or write into a dedicated 120K of core memory.

A MONITOR program which controls the data flow as well as the processing schedules has been implemented on the 360/91. The MONITOR is initiated by using the campus time shared URSA system through a CCI CRT terminal installed in the laboratory.

Among the various analysis softward on the 360 are pattern recognition programs to study and quantify the discriminability of data belonging to varying stimuli.

The IMLAC PDS-1 is a graphic computer which drives a slave display located in a window in front of the subject to provide visual feedback display. The IMLAC PDS-1 is primarily used in pattern related evoked response experiments, including variation of horizontal and vertical lines, faces, mazes etc.

DATA ACQUISITION

EEG RECORDING MACHINE

The EEG recording machine is a Grass Medical Instrument Model 6. The instrument uses plug in type units with color coded pushbuttons for electrode selection and regulated voltages, hybrid amplifiers (with 60 cycle filters).

The electrode board with the International Numeric System has 23 numbered jacks for all possible positions of electrodes.

A master gain and reduction control switch can adjust all channel amplifications.

ELECTRODES

The electrodes used in the experiments are surface disc silver chloride electrodes. A compound electrolyte is used to provide contact with the scalp and to secure the electrode. The area of the scalp is first prepared with alcohol and abrased slightly to eliminate skin oils and decrease scalp resistance.

ANALOG INPUT TO DIGITAL DATA CONVERSION

A/D CONVERTER

A SDS Model AD 20-11 made up of silicon semiconductor discretes which is capable of 30000 12-bit conversions per second is used. The converter is accurate up to 99.95%, accepts up to 10 volts, and has a visual display of the latest conversion. An aperture of up to 100 msec. can be realised with an optional sample and hold. The average conversion time is 33.3 microseconds. The converter has a self-contained reference voltage generator.

MULTIPLEXERS

One 16 channel and one 32 channel basic SDS MU31 multiplexers are installed.

D/A CONVERTER

Model DA 30-15 is used to convert 12 bits of parallel digital data. The converter is used to drive the analog plotter and a CRT.

IMPLEMENTATION OF 50 CHANNEL A/D CONVERSION

The analog input is converted to digital data using a complex of 4 A/D converters, 2 multiplexers and 3 D/A converters. The analog input data is sent to two of the ADC directly whereas the other two ADE's work with the two multiplexers by processing two channels at a time. The converted data from ADC #1 is sent to the left half of the 24 bit word and the converted data from ADC #2 is sent to its right half. The ADC outputs in a (10 data bits + 1 sign bit) register. Thirty-two channels would be processed in a little over 960 microseconds. A sampling time is usually one to eight milliseconds.

THE IMLAC PDS-1

The IMLAC PDS-1 is a graphical terminal and minicomputer which generates pattern display stimuli for the subject. It is a 8K dual processor in which the two processors share the same core memory. One of the processors is a conventional 16 bit minicomputer, whereas the other is a display processor.

The data processor has a cycle time of 2 μsec., direct addressing of 2K and indirect addressing up to 32K. It has one general purpose register plus one LINK bit. It allows immediate instructions and has parallel 16 bit I/O up to a maximum of 100K words per second with one level priority interrupt. It allows power/fail restart for core as well as for display information. Besides the usual set of instructions it has instructions for turning the display processor on, enable and disable interrupts, high voltage synchronization, continuous 2 msec intensification, TTY, paper tape and light pen.

THE IMLAC DISPLAY PROCESSOR

The display processor uses its own instruction set and is capable of decoding instructions as well. It steals memory cycles from the minicomputer when necessary. It can function in two modes; the Increment mode and the Processor mode. The later allows it to decode a small instruction set, whereas the former allows it to generate screen displays by decoding memory words into beam movements and corresponding intensification.

The long vector hardware allows it to draw lines up to full length of the screen as well as dotted lines.

The display in the sound proof subject's room operates in a slave mode to the display processor providing pattern display stimuli. The IMLAC PDS-1 generates displays and puts them on the screen before the experimenter on the master display independently of the slave display. The software for IMLAC includes a graphic design language (GRAL), SPACEWAR program and face-generating programs which are scheduled to be used in experiments.

THE XDS 920

The function of this computer is to acquire data from the analog to digital converter and to act as a scheduler of the real time experiment control. The DHS (Data Handling Supervisor) controls the real time collection of data, its analysis and display. It converses with the other computers by means of a 24 bit parallel data link which can operate at the rate of 40K bit per second through an interface box.

It is a computer suitable for on-line and real time systems that require high processing rates, complex I/O, and control functions. However it has a limited memory of 4096 words. The computer can handle up to 65K words per second in data transmission operation. It is a binary computer with a 2's complement facility and has a memory cycle time of 8 msec. It allows interrupts and uses a real time clock which can be programmed to produce timing pulses from 500 cps to 8000 cps to provide interupts.

The computer uses a XDS MAGPAK unit which facilitates programming and operation. It can be used to store library compilers and assemblers and could be bootstrapped in with ease. MAGPAK has two tape cartridges, each tape having a capacity of 2.8 million bytes of 6 bits plus parity each. The transfer rate is 1500 characters per second. It is used to hold: Library, Temporary Storage, Object programs and Source programs. A XDS 9150 card reader is also used which reads cards up to 100 cards per minute.

THE IBM 360/91

This campus machine provides the main computing power due to its exceptional large core memory and fast number crunching abilities. The computer is used through a CCI CRT terminal located in the laboratory under the campus-wide time-shared URSA system.

This computer houses the main data reduction and analysis software which can be used through the MONITOR program which is also installed on the 360 and controls the data flow between the lab and the 360 as well as the data analysis.

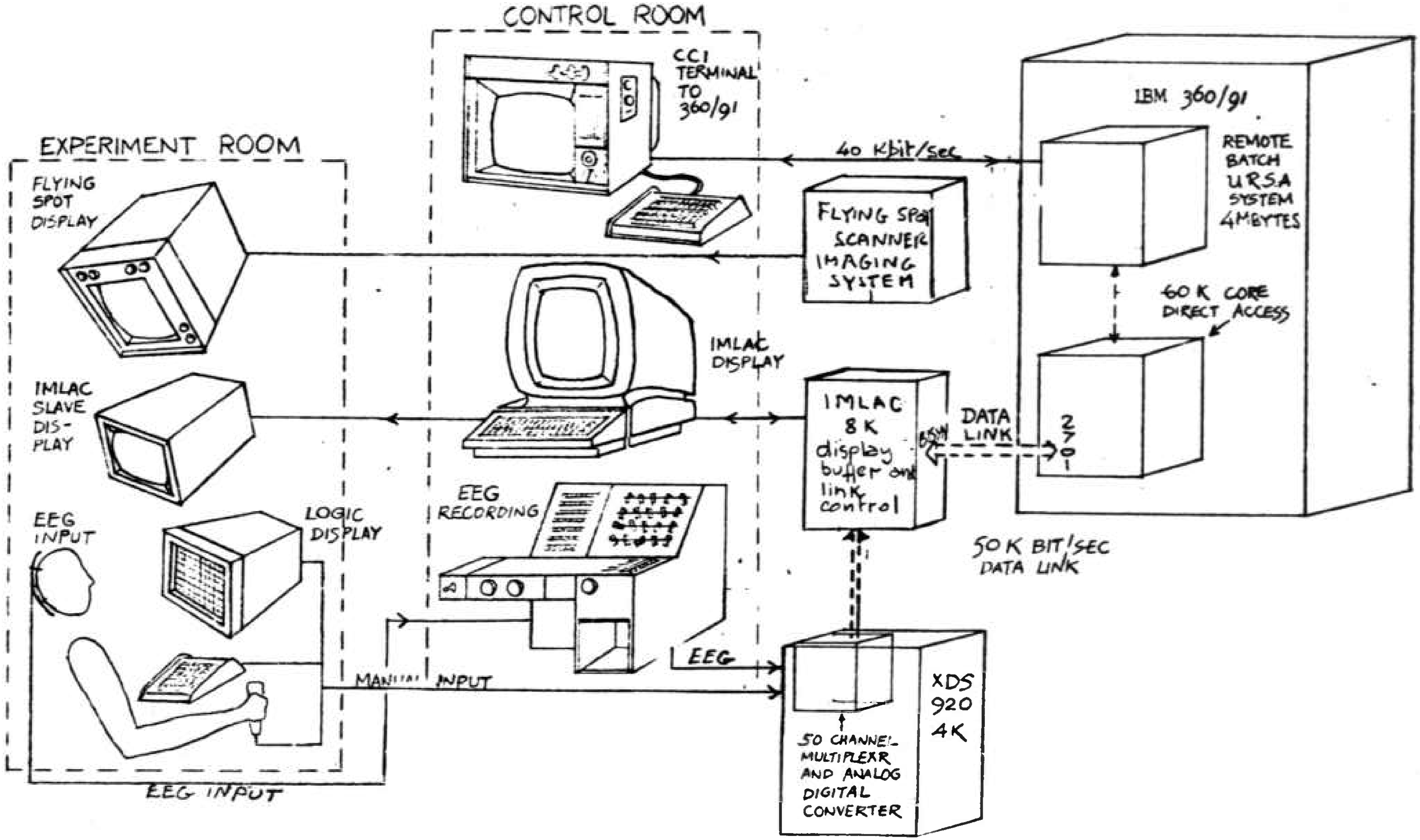
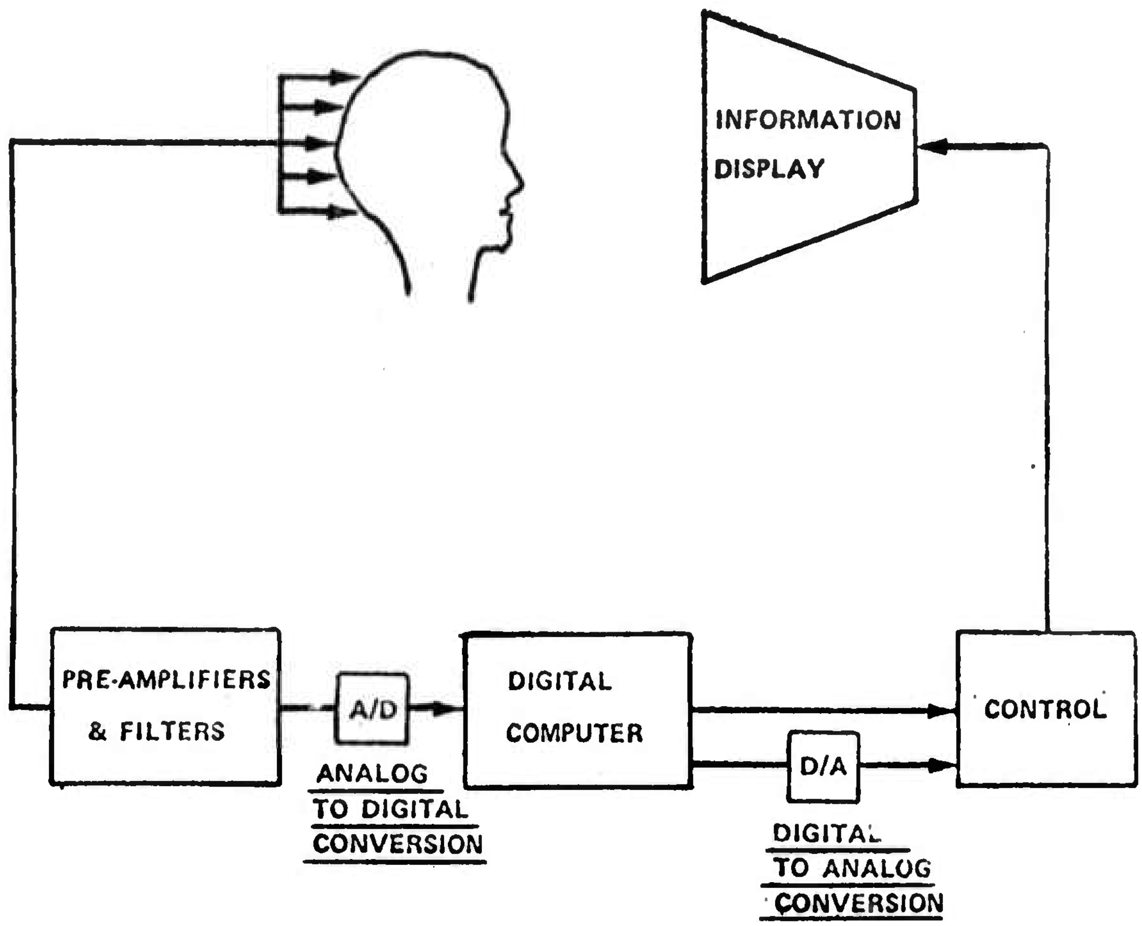


FIG. 31 THE BRAIN COMPUTER INTERFACE FACILITY



SYSTEM DIAGRAM OF A BRAIN COMPUTER-INTERFACE

FIG. 32